Arvin-Edison Water Storage District

1,2,3-Trichloropropane Mitigation Feasibility Study

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Executive Summary

Study Purpose

Arvin-Edison Water Storage District (the District) administers two groundwater banking programs: one groundwater banking program is for the direct benefit of the District's growers (the District Program) and a separate groundwater banking program in conjunction with the Metropolitan Water District of Southern California (the MWD Program). The purpose of both programs is to store excess surface water in the groundwater aquifer underlying the District during wet periods so that it can be pumped back out of the aquifer and returned to the District's growers and/or MWD during dry periods when surface water supplies are especially limited. The MWD Program relies on the California Aqueduct for delivery of banked water back to MWD. Water pumped into the California Aqueduct must meet California Code of Regulations Title 22 drinking water standards. Starting in 2017, the Title 22 standards include a maximum contaminant level (MCL) of 5 parts per trillion (ppt) for the synthetic organic contaminant 1,2,3-trichloropropane (TCP). The water recovered from almost all the program's recovery wells exceeds the TCP MCL. As a result, the MWD Program has been suspended until a solution to the problem can be identified, funded, and implemented. While there is not currently a regulatory limit for TCP in the water returned directly to the District's growers within its boundaries, the District is concerned that future regulatory action may result in restrictions to the District Program as well.

The purpose of this report is to document current and near-future costs incurred by the District due to suspension of the MWD Program; identify and evaluate all feasible alternatives for mitigating the impact of the TCP contamination on the groundwater banking programs; to recommend a preferred mitigation project; to present planning-level capital and O&M cost estimates for the preferred project; and to recommend next steps required for implementation of the project.

Impacted Sources

Water banked as part of both the District and MWD Programs is recovered from the groundwater aquifer using a total of 86 District-owned and operated groundwater wells and 5 grower in-lieu wells. Seventy-seven (77) out of the 86 District wells are known to be contaminated with TCP and 68 have exceeded the MCL. Some of the wells have produced water with TCP concentrations as high as 60 times the MCL value.

Project Design Criteria

Well capacity projections and historical operational records were reviewed to establish design criteria for use in evaluating alternatives for mitigating the contamination. The combined flow rate from the 68 District-owned wells that have exceeded the MCL is approximately 246 cfs. The five grower in-lieu wells produce an additional 13.9 cfs. The historical monthly operational records support the following assumptions regarding future MWD Program operations:

Table 1: MWD Program Design Criteria

Parameter	Value
Maximum MWD Program delivery rate[1]	175 cfs
Maximum MWD Program annual deliveries[1]	75,000-acre feet
Average annual MWD Program deliveries[2]	28,844-acre feet
Average annual MWD Program deliveries via Intertie Pipeline[2]	24,349-acre feet
Average annual recovery well production[2]	67,380-acre feet
Average annual recovery well production during Intertie Pipeline operations[2]	57,590-acre feet

[1] Contractual
[2] Based on historical values

Additional design criteria are:

1. That the water delivered to the California Aqueduct must have a TCP concentration reliably below 4 parts per trillion (which for practical purposes is non-detect);
2. The project must support the simultaneous operation of all of the District and in-lieu recovery wells; and
3. The project cannot result in the increase in another water contaminant likely to impact program operations (e.g. arsenic).

<u>Non-Treatment Mitigation Alternatives</u>

The study evaluated four non-treatment mitigation alternatives:

1. Wheeler Ridge water exchanges;
2. Operational adjustments;
3. Well replacement; and
4. Blending

The study concluded that all four non-treatment alternatives were not viable for various reasons and that treatment of the water would therefore be required.

<u>Treatment Mitigation Alternatives</u>

The study recommends treatment of the 68 District-owned and 5 in-lieu wells that have TCP concentrations exceeding the MCL. Granular activated carbon (GAC) was identified as the only viable treatment process for removing TCP from the water. The GAC treatment process has been used at many municipal TCP removal treatment plants and has proven to be simple and reliable. The process is passive, requires the addition of no chemicals, and does not rely on any significant automation. However; the carbon does have a limited useful life and must be replaced when it no longer effectively removes TCP from the water. When the carbon is replaced, the carbon needs to be backwashed in order to pre-condition it for service.

Three different GAC treatment configurations were further evaluated:

1. Wellhead treatment using steel pressure vessels
2. Centralized treatment plants at each of the North Canal, Sycamore, and Tejon Spreading Works combined with wellhead treatment of more remotely located wells; and
3. A single treatment plant located upstream of the Intertie Pumping Station

Alternative 1 – wellhead treatment would treat the water before it enters the District's canal system and would require 52 separate treatment plants utilizing a total of 418 12-foot diameter x 15-foot tall steel pressure vessels and over 8 million pounds of activated carbon. The carbon would need to be replaced in an average of 104 of those vessels each year. The addition of wellhead treatment plants downstream of the wells will create backpressure on the well pumps, which will result in a decrease in well production. Construction of 7 new wells to make up for the lost production capacity is proposed. Furthermore, all 7 of those new wells are assumed to also require treatment for TCP removal (the 7 "make-up" wells are included in the 52 treatment plants identified above).

Alternative 2 – centralized treatment plants at the North Canal, Sycamore, and Tejon Spreading Works would also treat the water before it enters the District's canal system, but would reduce the number of treatment plants. Because 5 of the North Canal, the 5 in-lieu, and the 7 make-up wells will be located remotely from the spreading works, it has been assumed that those wells will be treated with wellhead treatment plants as described for Alternative 1. The proposed centralized treatment plants would be large concrete structures similar to the filters used at large surface water treatment plants. The primary advantages over Alternative 1 are reduced capital costs and fewer facilities for the District to manage. The primary disadvantage of this alternative is that it is anticipated that the carbon life will be less than for the wellhead treatment plants in Alternative 1.

Alterative 3 – treatment upstream of the Intertie Pumping Station would utilize a single concrete, gravity treatment plant to treat only the water being delivered to the California Aqueduct. This would result in the lowest total treatment capacity (cfs) and the lowest volume of water treated (acre feet). However; once the water from the recovery wells enters the District's canal system, the water quality (for the purpose of treatment) degrades significantly. The combination of suspended solids, large debris, algae, and organics from intermingled imported water creates significant uncertainty that this approach will be successful or cost effective. Addition of a coagulant treatment chemical and the associated need for a residuals management system has been assumed. Even though this alternative reduces the volume of water that requires treatment, it is anticipated that operation and maintenance costs will be greater than the other two alternatives due to much higher carbon usage rates.

Analysis of Non-Treatment Cost Impacts

The District has incurred, and will continue to incur, costs and lost revenue as a result of the TCP contamination until a project is implemented to correct the problem. The following sources of cost and lost revenue were identified:

1. Cost for ongoing testing of the water for TCP;
2. Lost revenue from the MWD Program delivery and returned water regulation fees and from Kern Delta wheeling fees; and
3. Value of lost water from suspension of the Water Quality Sub Account program and leave-behind water from both the District/MWD and Kern Delta/MWD programs

The costs for TCP testing was $41,600 as of February 2021 and will increase $36,000 each year. The lost revenue and value of lost water are summarized in the following tables. These estimates assume that at a TCP mitigation project will be implemented towards the end of 2026.

Table 2: Lost Regulation and Wheeling Fees

Year	Lost MWD Fees	Lost KD Wheeling Fees	Lost Fees (Total Cumulative)
2019	$667,000	$0	$667,000
2020	$249,136	$0	$916,136
2021	$3,681,313	$834,848	$5,432,297
2022	$2,357,198	$415,111	$8,204,606
2023	$3,775,375	$672,685	$12,652,666
2024	$5,632,837	$1,003,642	$19,289,145
2025	$7,139,534	$1,054,766	$27,483,444
2026	$969,478	$0	$28,452,922
		TOTAL	**$28,452,922**

Table 3: Value of Lost Water

Water Year	WQSA (acre-feet)	MWD Leave Behind (acre-feet)	KD Leave Behind (acre-feet)	*Total Lost Water (acre feet)*	Cost of Water ($/AF)	Total Cost of Lost Water
2019	30,000	3,500	0	*33,500*	$250	$8,375,000
2020	0	0	0	*0*	$257	$0
2021	0	0	2,416	*2,416*	$261	$629,768
2022	0	132	1,170	*1,302*	$268	$348,367
2023	0	0	1,817	*1,817*	$279	$507,440
2024	0	0	2,727	*2,727*	$278	$757,098
2025	32,367	5,499	2,793	*40,658*	$285	$11,583,068
2026	31,446	4,331	0	*35,777*	$287	$10,284,362
					TOTAL	**$32,485,104**

Treatment Alternative Cost Comparison

Capital and operations & maintenance (O&M) costs for the three treatment alternatives were estimated and compared. The 50-year present worth cost for the three alternatives are summarized in the following table.

Table 4: Treatment Alternative Cost Comparison

	Cost (Million $)		
	Alternative 1 (Wellhead)	**Alternative 2 (Spreading Works)**	**Alternative 3 (Intertie Pipeline)**
Capital	$173.8	$125.8	$115.1
O&M (10 Years)	$67.8	$66.8	$97.0
O&M (20 Years)	$134.4	$132.5	$192.3
O&M (30 Years)	$200.4	$197.6	$286.7
O&M (40 Years)	$271.3	$267.5	$388.2
O&M (50 Years)	$344.4	$339.5	$492.7
Total (10 Years)	$241.6	$192.6	$212.1
Total (20 Years)	$308.2	$258.3	$307.4
Total (30 Years)	$374.2	$323.4	$401.8
Total (40 Years)	$445.1	$393.3	$503.3
Total (50 Years)	$518.2	$465.3	$607.8

Recommendation

The only way to fully mitigate the TCP contamination and restore the MWD Program's benefits is to treat a large portion of the water pumped from the contaminated recovery wells. The apparent lowest capital cost treatment approach is to construct a 175 cfs filter adsorber treatment plant at the Intertie Pipeline (Treatment Alternative 3). However, the estimated annual O&M costs for that alternative, and in particular the carbon usage rate, are expected to be significantly higher and have a much greater level of uncertainty than the other two alternatives. Given the anticipated high O&M costs and significant uncertainty associated with Alternative 3, it is recommended that the District implement Alternative 2: gravity GAC contactors at each of the spreading works. The lower O&M costs associated with Alternative 2 are predicted to offset the higher capital cost in less than 10 years. Alternative 2 would also provide the District with the flexibility of treating the water delivered to the District's growers should that be required in the future.

1 Background

1.1 Purpose of Report

Arvin-Edison Water Storage District (the District) administers two groundwater banking programs: one groundwater banking program is for the direct benefit of the District's growers (the District Program) and a separate groundwater banking program in conjunction with the Metropolitan Water District of Southern California (the MWD Program). The purpose of both programs is to store excess surface water in the groundwater aquifer underlying the District during wet periods so that it can be pumped back out of the aquifer and returned to the District's growers and/or MWD during dry periods when surface water supplies are especially limited. The MWD Program relies on the California Aqueduct for delivery of banked water back to MWD. Water pumped into the California Aqueduct must meet California Code of Regulations Title 22 drinking water standards. Starting in 2017, the Title 22 standards include a maximum contaminant level (MCL) of 5 parts per trillion (ppt) for the synthetic organic contaminant 1,2,3-trichloropropane (TCP). While the surface water percolated into the groundwater bank has no detectable level of TCP, the water recovered from almost all the program's recovery wells exceeds the TCP MCL. As a result, the MWD Program has been suspended until a solution to the problem can be identified, funded, and implemented. While there is not currently a regulatory limit for TCP in the water returned directly to the District's growers within its boundaries, the District is concerned that future regulatory action may result in restrictions to the District Program as well.

The purpose of this report is to identify and evaluate all feasible alternatives for mitigating the impact of the TCP contamination on the groundwater banking programs; to recommend a preferred mitigation project; to present planning-level capital and O&M cost estimates for the preferred project; and to recommend next steps required for implementation of the project.

1.2 Arvin-Edison Water Storage District

The District is comprised of approximately 132,000 acres of prime agricultural land located in the Southeasterly portion of the San Joaquin Valley in Kern County, California. The District oversees major infrastructure consisting of 45 miles of concrete canals, 50 pumping plants with 150 pumps, 1,650 acres of spreading basins, and 86 groundwater recovery wells. The District was organized in 1942 to contract with the United States for water and power service from the Central Valley Project (CVP). The need for CVP supplies was, at least in part, to address groundwater overdraft conditions that existed within the District at that time. The groundwater overdraft was estimated at 126,000 acre-feet per year. In 1962, the District entered into a water supply contract with the United States Bureau of Reclamation (USBR) to supply water from the Friant-Division of the CVP. The water supply contract provides for the annual delivery of 40,000 acre-feet of Class 1 (firm) water and up to 311,675 acre-feet of Class 2 (non-firm) water. The main facilities required to utilize this water supply were constructed between 1964 and 1968. In 1997, after more than 10 years of planning and negotiations, the District entered into a 25-year agreement with MWD to implement a water management program including water banking (the MWD Program). That agreement has since been extended out to 2035 with the option for further renewal.

The District is composed of two main water service areas: the Surface Water Service Area (SWSA) and the Groundwater Service Area (GWSA). The SWSA serves 51,420 acres with surface water and/or previously banked and recovered groundwater. The GWSA serves 68,225 acres with grower owned and operated farm wells. 14,470 acres of the GWSA are supplemented with temporary surface water supply from the District (when available), including growers participating in the District's In Lieu program.

1.3 1,2,3-Trichloropropane

1, 2, 3-trichloropropane is also known as allyl trichloride, trichlorohydrin, and glycerol trichlorohydrin and has the following physical properties:

Table 1-1: TCP Physical Properties

Property	Value
Chemical formula	$C_3H_5Cl_3$
CAS No.	96-18-4
Storet No.	77443
Molecular Weight	147.43
Density	1.38 g/cm^3
Solubility in water	1.75 g/L at 20°C
Vapor pressure	3.69 mm Hg at 25°C
Henry's Law constant	3.43 x 10^{-4} atm-m^3/mol at 25°C 22.83 x 10^{-4} Pa-m^3/mol at 25°C 0.013 dimensionless (K_{aw})
Octanol-water partition coefficient (Log K_{OW})	1.99; 2.54; 2.27 (various values reported)

In August 2009, the California Office of Environmental Health Hazard Assessment (OEHHA) established a California Public Health Goal (PHG) for TCP of 0.7 ppt, which is equal to 0.0007 µg/L. This is the second lowest California PHG level among all drinking water contaminants. The TCP PHG is based on carcinogenic effects and represents a one in one million lifetime cancer risk level assuming adults who drink two liters of water daily for 70 years. TCP is also on the list of chemicals known to the state to cause cancer. On July 18th, 2017 the State Water Resources Control Board Division of Drinking Water (DDW) voted to adopt a regulation for TCP with a maximum contaminant level of 5 ppt. Public drinking water systems were required to begin monitoring for TCP beginning the first quarter of 2018.

2 Arvin-Edison Water Banking

2.1 Banking Programs

Because the District's imported Class 2 CVP water supply is highly unpredictable, the District has had to find innovative means of regulating the variable supply to meet a relatively constant irrigation demand by the District's growers. This has historically been accomplished through groundwater banking operations in combination with water exchanges and transfers. This section describes the District's groundwater banking programs.

2.1.1 MWD Program

The District's water banking program with MWD was designed to enhance efficient use of available water supplies and water banking facilities for both parties. For MWD, the program allows it to regulate up to 350,000 acre-feet in the bank to enhance dry year supplies. For the District, the program generates significant benefits in the form of revenue from fees charged to MWD for Program operations; improved water supply reliability in the form of a 10% leave behind of banked water; and enhanced facilities. As part of the program, the District expanded its spreading works by 500 acres, added 17 new groundwater wells and constructed a 4.3-mile, bi-directional Intertie Pipeline and pump station connecting the terminus of the District's South Canal directly to the California Aqueduct. These facilities were constructed in the late 1990's, with substantial completion in 2000. The District has imported and stored approximately 665,000 acre-feet of MWD water since December 1997 utilizing the Cross-Valley Canal (CVC) and Intertie Pipeline to transport predominantly State Water Project (SWP) water to the District's spreading works. Return of a portion of the water to the SWP California Aqueduct through the Intertie Pipeline began in January 2003 (by exchange before then). The MWD Program agreement was amended in 2008 and will expire in 2035 subject to extension.

In addition to the primary groundwater banking program, the District and MWD operate a related Water Quality Sub Account (WQSA) program as part of the MWD Program. The overall objective of the WQSA is to provide MWD additional water quality benefits by delivering water generally during the spring in exchange for MWD providing the District with additional surface water in the fall. The District has made extensive use of the WQSA program to take advantage of available spring runoff flows that the District would otherwise not have been able to capture. A typical operational scenario involves the availability of runoff water from spring storms during periods of time when the District cannot take delivery of the water due to low grower water demand and the spreading works basins operating full. When this occurs, the District delivers the runoff water to MWD, which then returns the water, in the form of California Aqueduct water when the District has the capacity to accept it. Continued use of the WQSA program is now suspended until the TCP issue is resolved.

The current MWD Program conditions and obligations are defined in the *First Amended and Restated Agreement Between Arvin-Edison Water Storage District and the Metropolitan Water District of Southern California for a Water Management Program* (Program Agreement), dated October 9, 2007. The original agreement was dated December 19,1997. The current agreement terminates on November 4, 2035 subject to renewal. The District's contractual obligations under the MWD Program Agreement are summarized in the following table.

Table 2-1: MWD Program Agreement Conditions

Condition	Requirement
Capacity of gravity flow from Aqueduct into the South Canal	127 cfs
Capacity of pumping from the South Canal into the Aqueduct	175 cfs
Maximum regulation capacity	350,000 acre-feet
Return method	Banked groundwater into the California Aqueduct through the Intertie Pipeline and/or through exchange of water using the California Aqueduct or CVC
Assumed losses (leave behind)	10% of water delivered by MWD to the bank
Annual regulation volume	AEWSD is not required to accept more than 45,000 acre-feet in any water year
Annual return volume	40,000 – 75,000 acre-feet per year
Water quality	As described in the DWR Water Quality Assessment of Non-Project Turn-ins to the California Aqueduct. Water must meet California Title 22 drinking water standards.

2.1.2 District Program

The District's banking facilities primarily serve growers within the District's boundaries. While the MWD Program uses the same infrastructure as the District's program, District banking operations have priority of use of the facilities over the MWD Program. The District banks predominantly CVP water delivered via the Friant-Kern Canal (FKC) and Kern River but also banks water from the California Aqueduct, CVC, and systems connected to those canals. The same recovery wells are used to withdraw water for the District's growers that are used for the MWD Program. However, since water for the District Program is used within the District and does not enter the California Aqueduct, there are currently no regulatory or contractual restrictions on the concentration of TCP in the water. This could change if there is further regulatory action in the future.

2.1.3 Other Banking Programs

The District also participates in groundwater banking projects whereby the District banks its water with other agencies using their aquifers and recovery wells (e.g. Rosedale-Rio Bravo Water Storage District). Additionally, the District, in partnership with Kern Delta Water District, is in the design phase of a project to develop a new approximately 160-acre spreading basin (the Sunset Groundwater Recharge Facility) near the District's Western boundary southeast of the community of Lamont. The plans for the Sunset Groundwater Recharge Facility do not currently include recovery wells. TCP impacts on operation of these other programs are not included in the scope of this feasibility study and are not discussed further in this report.

2.2 Sources of Banked Water

In addition to natural recharge of the aquifer, there are several sources of water that have the potential to percolate into the District's water bank. They are the:

1. California Aqueduct
2. Friant Kern Canal (FKC)

3. Kern River
4. Kern Delta Water Storage District wells (7 wells)
5. Grower in-lieu Wells (5 wells)
6. Farm Well Pump-in Program wells
7. Sources connected to these facilities including Kings River flood waters via the Delta Lands Reclamation District #770 (DL770)

Administratively, only California Aqueduct water is banked for MWD. However, all of the above water sources that may be imported at any given time are freely intermingled within the District's canal system prior to arriving at the groundwater bank spreading basins.

2.2.1 Surface Water Sources

Water delivered from the California Aqueduct, FKC, CVC, and Kern River is predominantly surface water with contributions from pump-in wells along the canals. All of these sources can enter the District's system at the headworks of the District's Intake Canal. California Aqueduct water can also enter the District's system via gravity flow in the District's Intertie Pipeline. The District actively monitors potential water quality impacts from existing and proposed programs involving these sources. Since 2008, eighty-two comment letters have been issued by the District regarding potential impacts to FKC water quality alone. Provost & Pritchard was unable to find any record of TCP having been detected in any of these surface water sources. However, it is probable that some TCP may make its way into the CVC supply through discharges from other groundwater banking programs with TCP-contaminated wells (e.g. the Rosedale-Rio Bravo Water Storage District program).

2.2.2 Kern Delta Water Storage District Wells

Kern Delta Water Storage District (Kern Delta) also operates a water banking program in conjunction with MWD. That program is considerably smaller than the District's program. Kern Delta utilizes the AEWSD Intake Canal to deliver banked water pumped from seven Kern Delta recovery wells to MWD and MWD uses the canal to deliver water to Kern Delta for the MWD/Kern Delta banking program. Kern Delta's recovery wells are also impacted by TCP contamination. Kern Delta's banking program with MWD has been impacted due to both the presence of TCP in its recovery wells and its current inability to utilize the AEWSD canal system to convey the water banked within Kern Delta to MWD.

2.2.3 Grower In-Lieu Wells

The District's Grower In-Lieu program involves the delivery of surface water to Growers within the District's groundwater service area during wet years. In return, the District can call on the participating growers to deliver pumped groundwater to the District's canal system during dry years. The physical infrastructure necessary to support the Grower In-Lieu program was recently constructed at five grower wells. However, these wells have not yet been used for in-lieu operations. All five wells have levels of TCP that exceed the MCL value.

2.2.4 Farm Well Pump-in Program Wells

The Farm Well Pump-in Program allows the District's growers to utilize the District's conveyance facilities to move their pumped groundwater from one part of the District's service area to another. Prior to the TCP regulation, nine (9) grower wells were approved by the Aqueduct Pump-in Facilitation Group to pump-in during MWD deliveries. However, forty-two (42) grower wells have been connected to the transmission canal system but have not yet been approved by the Aqueduct Pump-in Facilitation Group. TCP levels for the Farm Well Pump-in wells have not yet been tested. At the District's request, the impacts of TCP on the Farm Well Pump-in Program have not been evaluated as part of this study.

2.3 Return of Banked Water

When groundwater is recovered from the District's banking facilities using its recovery wells, all water flows through one or more segments of the Arvin-Edison transmission canal system (North Canal, South Canal, and Intertie Pipeline) and is pumped into the California Aqueduct at the Intertie Pump Station. There is no other means of getting the recovered groundwater to the California Aqueduct for delivery to MWD or any other banking partner. While in the transmission canals, the recovered water is intermingled with water being recovered from the bank for the District's banking program and with any surface water that is being delivered through the Intake Canal.

The District does have limited opportunities to "wheel" water from various non-groundwater bank sources through paper and/or physical exchanges to supply a portion of the MWD or other water recovery requests. This includes water exchanges enacted using temporary consolidated place of use (CPOU) agreements that allow CVP water to be sent to MWD. However, the circumstances under which exchanges can occur are limited and the District has historically only supplied a small percentage of the water recovered for MWD through exchanges.

2.4 Infrastructure

The facilities location map in Figure 2-1 shows the locations of the major infrastructure associated with the water banking programs. The major facilities are described in more detail in the following sections.

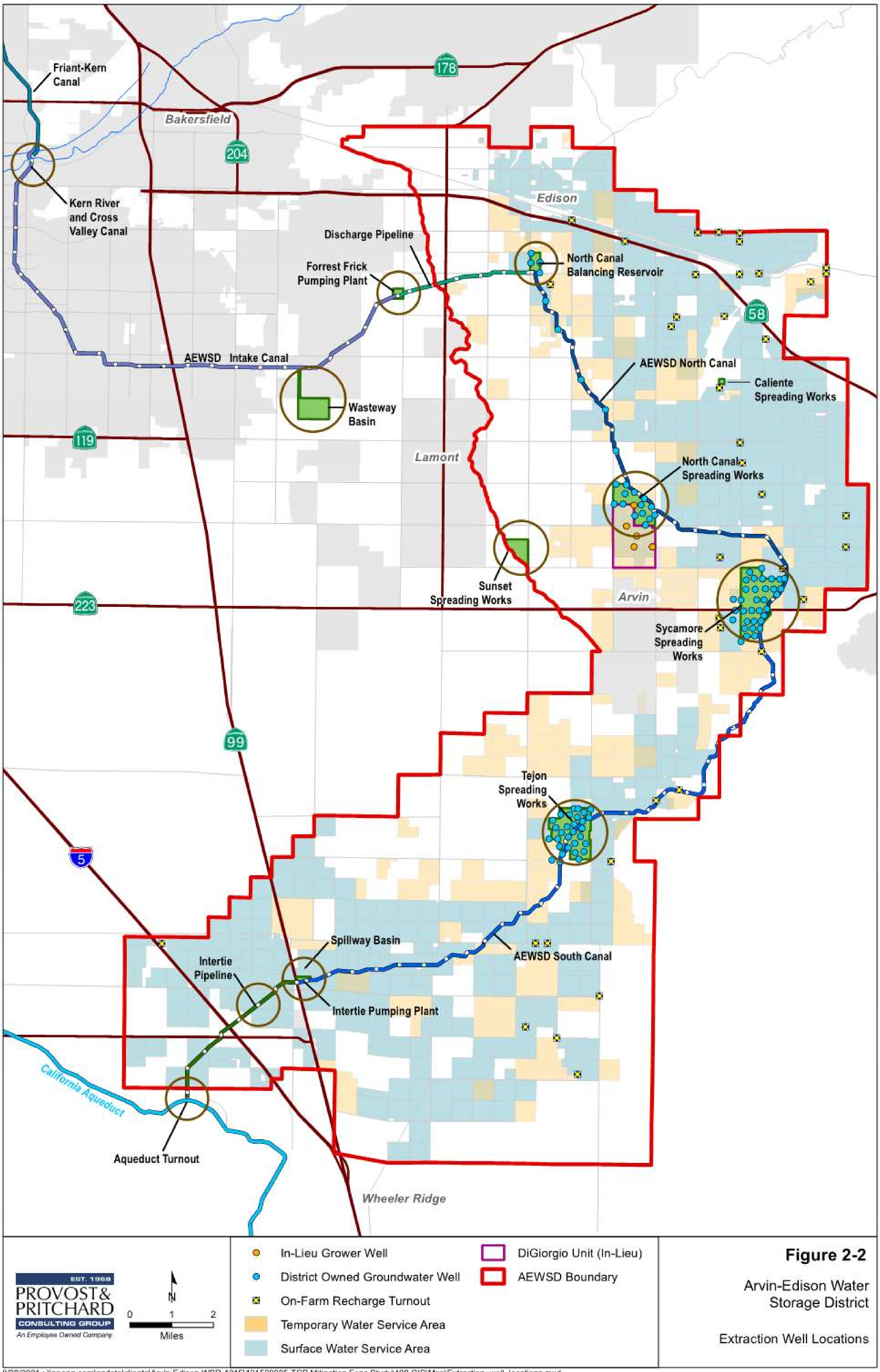


Figure 2-1: Facilities Map

2.4.1 Kern River / Cross-Valley Canal Turnout

The headworks of the AEWSD Intake Canal (refer to Figure 2-2) is located in west-central Bakersfield. The headworks consists of a complicated series of turnouts, siphons, and pumping stations that permit water from one or more of the CVC, Kern River, FKC, and Carrier Canal to enter the District's Intake Canal. SWP water from the California Aqueduct is routed through the CVC before entering the Intake Canal.

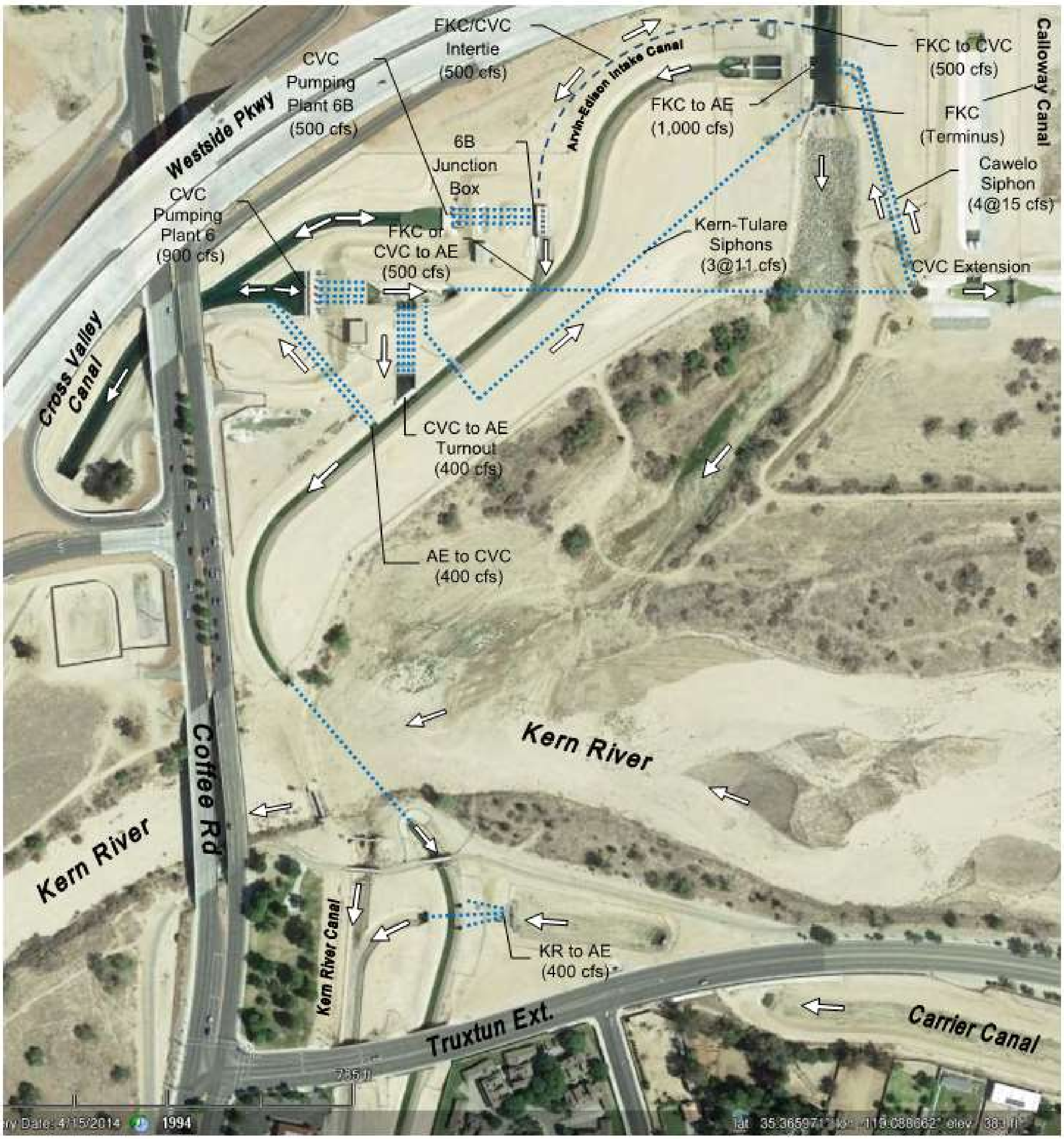


Figure 2-2: AEWSD Intake Canal Headworks

2.4.2 Primary Conveyance Facilities

The District's primary conveyance facilities, in order from north to south, which is the primary direction of flow, consist of the:

- FKC/CVC/Kern River Headworks;
- Intake Canal;
- Wasteway Basin;
- Forrest Frick Pumping Plant;
- Forrest Frick Pipeline;
- Balancing Reservoir;
- North Canal;
- South Canal;
- Spillway Basin;
- Intertie Pipeline and Pumping Plant; and
- Aqueduct Turnout

Connected to these primary transmission facilities between the Balancing Reservoir and the southwestern boundary of the District's service area is the District's grower distribution system, which consists of pumping plants, pipelines standtanks, and turnouts (serving lands with up to six pump lift zones).

These facilities are all arranged in series from the FKC/CVC/Kern River headworks near the northwest edge of the system to the Intertie Pipeline at the southwestern corner of the District's service area. Although water typically flows from north to south, the District has pump-back stations that permit limited flow in the opposite direction. Approximately 130 cfs can be pumped from the lower pool with the Intertie Pump Station to the pool between the Tejon Spreading Works and the Sycamore Spreading Works. Approximately 50 cfs can be pumped from the pool south of the North Canal Spreading Works to the pool north of those spreading works.

2.4.3 Spreading Works

The entire conveyance system, with the exception of the Balancing Reservoir and Spillway Basin, is either piped or concrete lined, which constrains groundwater recharge to occur primarily at the following unlined basins and dedicated spreading works:

- Balancing Reservoir;
- Caliente Spreading Works;
- North Canal Spreading Works;
- Sycamore Spreading Works;
- Tejon Spreading Works;
- Sunset Groundwater Recharge Facility (anticipated to be fully functional by Fall 2022); and
- On-Farm Recharge.

The Balancing Reservoir as its name implies is intended to provide operational flexibility by balancing the flows from the Forrest Frick Pumping Plant with downstream water demands. Any percolation that occurs there is incidental. The Caliente, North Canal, Sycamore, and Tejon Spreading Works were designed specifically to facilitate efficient percolation of water into the groundwater bank. Water flows by gravity into the lower elevation ponds at each of the spreading works. The water must be pumped from the canal to the higher elevation ponds. The District is currently developing the Sunset Groundwater Recharge Facility southeast of the community of Lamont. During 2019, the District also enacted a program with some of its growers to purposefully apply water to fallowed land for the purpose of groundwater recharge.

2.4.4 Recovery Wells

Water banked as part of both the District and MWD Programs is recovered from the groundwater aquifer using a total of eighty-six (86) District-owned and operated groundwater wells and five (5) grower in lieu wells in the vicinity of the North Canal Spreading Works. The wells are distributed throughout the system as follows:

Table 2-2: Recovery Well Locations

Location	Well Quantity
Balancing Reservoir	4
North Canal Alignment	5
North Canal Spreading Works	14
Sycamore Spreading Works	34
Grower In Lieu Wells (near North Canal Spreading Works)	5
Tejon Spreading Works	29

At any given time, approximately four of the remaining 82 wells are also out of service for maintenance. The District is currently implementing a program to gradually expand recovery capacity by constructing new wells. The ultimate goal of the program is to be able to supply the peak demand of the District's growers entirely from pumped groundwater during drought years. Because the conveyance system design (gravity flow from north to south) limits the District's ability to move water from south to north, most of these future wells will likely need to be constructed in the northern part of the District, where TCP levels tend to be highest.

Recovery of water from the groundwater bank can also occur through pumping of the five Grower-owned in-lieu wells. Although these grower in-lieu wells are not part of the MWD Program banking facilities, the grower wells are expected to be in operation at the same time that MWD water is being returned. The water from the grower in lieu wells will intermingle with water from the District's recovery wells in the canal system.

The pumping capacity of each of the recovery wells varies over time depending on when the well was last rehabilitated and on seasonal variation in pumping water levels, which in turn vary with hydrologic conditions and the history of imported water deliveries to the spreading basins. The estimated maximum pumping capacities of the District's wells are summarized in Table 2-3. These values are based on the water year 2020 values from the District's 2020 – 2022 water year production estimate and adjusted up by 10% to account for the lower-than-average pumping water level conditions during 2020. Values for wells 34, 82, 91, 97, N15, N16, N17, and N18, which are currently out of service, were taken from the District's 2018 production estimate.

Table 2-3: Maximum Well Pump Capacities

Sycamore Well Field		
Well No.	Production (CFS)	Production (GPM)
1	2.97	1,331
2	2.61	1,171
4	3.60	1,614
5	3.92	1,758
6	3.41	1,532
7	3.32	1,491
8	3.52	1,579
9	2.71	1,216
10	2.99	1,341
11	4.06	1,821
12	3.54	1,588
13	2.75	1,235
14	2.80	1,256
15	2.52	1,131
16	2.22	996
17	1.95	874
18	2.24	1,004
20	3.82	1,712
21	2.13	958
22	3.46	1,552
23	3.90	1,748
24	3.67	1,648
25	3.72	1,671
26	3.06	1,375
28	4.05	1,816
29	3.15	1,416
31	3.18	1,428
32	3.63	1,629
33	2.99	1,343
34	1.71	767
35	2.26	1,014
36	2.91	1,308
37	3.00	1,349
38	4.20	1,884

Tejon Well Field		
Well No.	Production (CFS)	Production (GPM)
71	2.85	1,280
72	3.19	1,432
73	3.38	1,515
74	1.93	868
75	2.70	1,211
76	2.79	1,251
77	2.47	1,110
78	2.31	1,037
79	3.04	1,364
80	2.16	969
81	3.08	1,383
82	3.22	1,445
83	2.06	924
84	2.99	1,340
86	2.83	1,271
87	2.64	1,183
88	2.82	1,267
89	1.83	823
90	2.75	1,234
91	2.60	1,167
92	4.09	1,835
93	3.96	1,775
94	4.21	1,888
95	1.31	590
96	1.50	672
97	Abandoned	Abandoned
98	5.94	2,667
99	5.70	2,558
100	6.93	3,111
101	6.93	3,111

North Canal Well Field		
Well No.	Production (CFS)	Production (GPM)
N1	3.32	1,492
N2	3.20	1,437
N3	3.78	1,697
N4	3.41	1,532
N5	3.79	1,702
N6	2.98	1,339
N7	4.25	1,906
N8	2.99	1,343
N9	2.67	1,198
N10	2.95	1,322
N11	3.39	1,522
N12	4.25	1,907
N13	2.87	1,289
N14	2.75	1,232
N15	0.82	368
N16	1.02	458
N17	1.07	480
N18	1.63	732
N19	7.15	3,210
N20	7.34	3,292
N21	7.44	3,338
N22	7.28	3,266
N23	7.28	3,266

The District's total combined recovery well pumping capacity is approximately 288 cfs (129,200 gpm) excluding the grower in-lieu wells.

2.4.5 Intertie Pipeline and Pump Station

The South Canal terminates at the Spillway Basin where water can flow from the California Aqueduct into the District's canal system by gravity or from the District's canal system into the California Aqueduct through a pumping station. Gravity flow is limited to 127 cubic feet per second (cfs). The pumping station, which consists of seven pumps, is capable of delivering up to 175 cfs to the California Aqueduct. Some water does bypass the Intertie Pipeline and Pump Station to serve growers in the Mettler area.

2.4.6 Flow Measurement

Banking program recharge and recovery volumes are monitored as follows:

Parameter	Measurement
Recharge (Spreading)	Propeller flow meters with totalizers and overflow weirs with staff gauges are used to monitor the volume of water entering the spreading works. These instruments are read daily during spreading operations.
Recovery (Extraction)	Each recovery well is equipped with a totalizing flow meter. These meters are read on a daily basis when in operation.
Deliveries to the California Aqueduct	An ultrasonic flow meter located in the Intertie Pipeline measures flows to and from the California Aqueduct

2.5 Operational Constraints

By the very nature of the District's and MWD's groundwater banking programs, recovery from the bank for both programs typically occurs during "dry" years when surface water supplies are particularly limited. Relevant consequences of this are that:

1. Recovery from the bank to serve the District's customers tends to occur during the same years and months that recovery for the MWD Program occur;
2. The total groundwater bank recovery capacity necessary to meet the needs of the District's and MWD's banking programs requires simultaneous operation of most, if not all, of the District's recovery wells; and
3. Imported surface water deliveries via the Intake Canal are generally limited during the time periods when groundwater is being recovered from the bank.

3 Water Quality

The following sections summarize water quality data for the recovery wells, imported surface water supplies, and at the Intertie Pipeline. The following table summarizes how these selected constituents may affect the potential mitigation project alternatives.

Table 3-1: Relevant Water Quality Constituents

Constituent	Significance
1,2,3-Trichloropropane (TCP)	Targeted contaminant.
1,2-Dibromo-3-Chloropropane (DBCP)	Synthetic organic contaminant used in soil fumigants frequently found together with TCP. Competes with TCP for activated carbon adsorption capacity.
Total Organic Carbon (TOC)	Primarily naturally occurring background organic compounds that will compete with TCP for activated carbon adsorption capacity.
Iron	Inorganic contaminant that has the potential to foul activated carbon and reduce carbon life.
Manganese	Inorganic contaminant that has the potential to foul activated carbon and reduce carbon life.
Total Suspended Solids (TSS)	Quantifies the solids present in surface waters and, to a lesser extent, groundwater. Solids will be captured by activated carbon beds leading to head loss build up and the need for backwashing.
Turbidity	Measurement of the clarity of water. Can be used as an indirect measurement of suspended solids.
Hardness	High hardness waters can foul activated carbon.
Nitrate	Inorganic contaminant that, when present in moderately high concentrations, can build up on activated carbon and be released at high levels over short periods of time – a phenomenon commonly referred to as "sloughing".

The District began analyzing water samples for TCP beginning the first quarter of 2018, the same quarter that public drinking water systems were required to begin monitoring. Extensive follow-up testing was performed the second quarter of 2018 and again in 2020. Most wells have been monitored quarterly since 2020. Ranges of measured TCP levels for each of the District's recovery wells are presented in Tables 3-2 through 3-4. The TCP results for the five grower in lieu wells are presented in Table 3-5. A full summary of TCP results for the District's recovery wells and Grower In Lieu wells is contained in **Appendix A**.

DBCP results were only available for the FKC. Nitrate data was available for most sources, but it was not always clear whether the reported units were reported as nitrogen (N), or as nitrate (NO_3). In most cases it was assumed that the results represented the concentration of NO_3.

Where no data was available, the table cell has been shaded. Where multiple data points were available, ranges of values have been presented.

3.1 Recovery Well Water Quality

Water quality data for the District's North Canal, Sycamore, and Tejon recovery wells is presented in Tables 3-2 through 3-4. Water quality characteristics of note include:

- TCP concentrations typically exceeding the MCL and in many cases more than 25 times the MCL
- Very hard water in the most northerly wells
- Relatively low, but still significant, iron and manganese levels in the North Canal wells;
- Low to moderate background TOC levels in all wells; and
- Nitrate levels in most wells are low enough that sloughing of nitrate off of activated carbon should not be an issue. However, for wells with levels higher than 22 mg/L (as NO3), short nitrate sloughing events are possible.

Table 3-2: North Canal Well Water Quality

Wells		TCP (µg/L)		TOC (mg/L)	Iron (µg/L)	Manganese (µg/L)	TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L)	
		Min	Max					Min	Max	Min	Max
North Canal Wells	N1	0.036	0.0689	0.279	50	ND	0.56	200	410	7.5	45
	N2	0.02	0.132	0.527	43	340	3.3	200	520	20	100
	N3	0.032	0.203	0.413	51	94	ND	330	450	54	110
	N4	0.028	0.0816	0.363	47	18	0.56	86	380	0.68	78
	N5	0.136	0.326	0.358	46	ND	3.4	290	360	45	89
	N6	0.16	0.53	0.15	44	7.3	ND	130	180	1.4	19
	N7	0.114	0.233	0.299	41	24	ND	68	93	1.4	2.8
	N8	0.0813	0.341	0.15	34	ND	ND	130	170	0.27	2.1
	N9	0.086	0.27	0.15	43	ND	0.56	97	130	14	25
	N10	0.098	0.288	0.15	39	ND	0.89	29	71	5.3	24
	N11	0.077	0.244	0.15	39	ND	ND	80	110	0.26	0.89
	N12	0.0664	0.114	0.15	35	ND	ND	36	56	2.3	4.1
	N13	0.0945	0.3	0.227	43	11	ND	77	130	0.11	1.2
	N14	0.157	0.292	0.15	44	ND	ND	200	340	28	82
	N15	ND	ND	0.5				120	220	0	2.2
	N16			0.6				130	310	0	15
	N17	ND	ND	0.5				41	220	0	17
	N18	ND	ND	0.6				130	250	1.2	6.5
	N19	0.0785	0.197	0.15	38	6.6	ND	97	100	3.8	6.3
	N20	0.0251	0.12	0.15	35	ND	2.8	70	120	4.3	9.2
	N21	0.0328	0.11	0.15	34	ND	1.1	78	78	4.5	4.5
	N22	0.032	0.0717	0.3	ND	ND	10	94	94	5.6	5.6
	N23	0.0724	0.139	0.5	ND	ND	0.67	110	110	9.4	9.4

Table 3-3: Sycamore Well Water Quality

Wells		TCP (µg/L)		TOC (mg/L)	Iron (µg/L)	Manganese (µg/L)	TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L)	
		Min	Max					Min	Max	Min	Max
Sycamore Wells	1	0.00412	0.0461	0.15	ND	ND	0.56	67	100	4.6	18
	2	0.00173	0.00834	0.3	34	ND	0.78	74	120	4.3	22
	4	ND	0.0216	0.15	ND	ND	0.56	59	120	5.9	20
	5	0.00194	0.0197	0.154	ND	ND	1.1	68	89	4.1	13
	6	0.00694	0.0295	0.3	ND	ND	1.1	52	78	0	7.4
	7	0.00572	0.00965	0.202	ND	ND	0.89	52	81	3.4	11
	8	0.00172	0.0198	0.15	ND	ND	0.67	61	110	3.5	14
	9	0.0125	0.0374	0.169	ND	ND	1.7	45	89	3	17
	10	ND	0.0129	0.3	ND	ND	0.89	49	66	2.2	10
	11	0.00698	0.057	0.15	ND	ND	0.67	42	88	2.7	9.3
	12	ND	0.0367	0.3	ND	ND	ND	0	78	0	13
	13	ND	0.00457	0.3	31	ND	0.56	34	100	1.1	10
	14	0.00308	0.00836	0.15	ND	ND	56	12	130	0.5	4.5
	15	ND	0.00103	0.3	ND	ND	ND	25	62	3.8	28
	16	ND	0.00108	0.3	ND	ND	ND	35	53	7.5	33
	17	ND	ND	0.3	ND	ND	3.7	31	250	6.9	24
	18	ND	ND	0.3	ND	ND	0.56	48	86	1.2	8.9
	20	ND	0.0292	0.15	ND	ND	ND	0	83	0	17
	21	0.0014	0.02279	0.176	ND	ND	0.56	59	78	4.8	7.4
	22	0.0173	0.0408	0.279	ND	ND	ND	0	93	0	8.2
	23	0.0167	0.0599	0.229	ND	ND	ND	76	150	6.2	24
	24	0.00562	0.131	0.197	ND	ND	ND	56	110	3.6	17
	25	0.00302	0.0169	0.191	ND	ND	0.88	72	200	3.4	27
	26	0.00124	0.0185	0.334	ND	ND	1.4	55	150	2.6	10
	28	ND	0.00683	0.15	ND	ND	1.4	65	93	0.87	2.5
	29	ND	0.00289	0.187	ND	ND	1	58	110	0.38	2.8
	31	ND	0.028	0.15	ND	ND	ND	61	92	0.22	0.93
	32	ND	0.00112	0.5	ND	ND	ND	36	94	4.6	83
	33	ND	0.00377	0.5	ND	ND	ND	39	68	15	66
	34			0.3				0	36	0	32
	35	ND	ND	0.193	ND	11	ND	16	19	0.27	9.6
	36	ND	0.0184	0.264	ND	24	0.56	22	62	0.17	0.8
	37	0.0017	0.0292	0.291	ND	53	3.2	33	73	0.11	0.52
	38	ND	ND	0.15	ND	ND	1.1	19	22	6.1	7.9

Table 3-4: Tejon Well Water Quality

Wells		TCP (µg/L)		TOC (mg/L)	Iron (µg/L)	Manganese (µg/L)	TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L)	
		Min	Max					Min	Max	Min	Max
Tejon Wells	71	ND	0.00563	0.742	ND	ND	3.3	0	120	0	120
	72	ND	0.00678	0.261	ND	ND	0.78	0	170	0	170
	73	0.00337	0.0112	0.317	ND	ND	ND	110	210	0.00337	210
	74	ND	0.00145	0.3	ND	ND	0.57	110	130	0.00145	130
	75	ND	0.0051	0.2	ND	ND	ND	98	130	0.0051	130
	76	ND	0.00806	0.276	ND	ND	ND	80	130	0.00806	130
	77	ND	ND	0.206	ND	ND	ND	73	130	0.206	130
	78	ND	0.00292	0.252	ND	ND	ND	80	150	0.00292	150
	79	0.00336	0.0171	0.429	ND	ND	ND	79	200	0.00336	200
	80	ND	0.01	0.15	ND	ND	ND	93	140	0.01	140
	81	ND	0.00143	0.18	ND	ND	0.67	95	120	0.00143	120
	82	0.005	0.005	0.6				0	150	0	150
	83	ND	0.00236	0.275	ND	ND	ND	96	140	0.00236	140
	84	0.00554	0.0244	0.3	ND	ND	ND	92	160	0.00554	160
	86	0.00309	0.009	0.3	ND	ND	1.4	0	130	0	130
	87	0.00999	0.054	0.178	ND	ND	ND	0	190	0	190
	88	0.155	0.437	0.15	ND	ND	ND	0	310	0	310
	89	0.0128	0.0507	0.186	ND	ND	ND	110	180	0.0128	180
	90	ND	0.006	0.15	ND	ND	ND	100	150	0.006	150
	91			0.3				99	150	0.3	150
	92	0.0915	0.313	0.191	ND	ND	ND	0	200	0	200
	93	0.0202	0.0528	0.211	ND	ND	1.7	0	160	0	160
	94	0.012	0.0238	0.38	ND	ND	ND	150	230	0.012	230
	95	0.0143	0.0143	0.5				0	72	0	72
	96	0.007	0.031	0.396	ND	ND	ND	0	260	0	260
	97							0	0	0	0
	98	0.01	0.0172	0.15	ND	ND	5.1	150	170	0.01	170
	99	0.012	0.057	0.209	ND	ND	ND	160	220	0.012	220
	100	0.0141	0.0349	0.23	ND	ND	3	120	130	0.0141	130
	101	0.019	0.03	0.15	ND	ND	2	160	160	0.019	160

3.2 In-Lieu Well Water Quality

Water quality data for the five Grower In-Lieu wells is summarized in Table 3-5.

Table 3-5: Grower In Lieu Well Water Quality

Wells	TCP (µg/L)	TOC (mg/L)	DBCP (µg/L)	Iron (µg/L)		Manganese (µg/L)	TSS (mg/L)	Hardness (mg/L)		Nitrate as N (mg/L)	
				Min	Max			Min	Max	Min	Max
D-1	0.48	ND		89	89	ND		260	260	11	11
D-2	0.73	ND		ND	31	ND	50	210	250	13	19
D-3	0.201	ND									
D-4	0.175	ND		ND	ND	ND		180	180	11	11
D-5	0.055	ND		ND	ND	ND	2.1	58	65	3	4

3.3 Surface Water Quality

The quality of the District's imported surface water was considered to confirm that it was not a potential source of the TCP contamination. It was also considered in evaluating the Intertie Pipeline centralized treatment mitigation alternative since these surface water sources have the potential to intermingle with recovered well water in the District's transmission canal system prior to treatment.

Provost & Pritchard did not find any water quality data that would indicate that TCP is present in imported surface water supplies at a concentration high enough to cause the groundwater contamination. However, it is known that some groundwater wells operated by other water districts (e.g. Rosedale-Rio Bravo Water Storage District) are contaminated with TCP and, at times, discharge into the CVC. Regardless, to the extent that any de minimis TCP may be present in the imported surface water, it is not material to the impacts and potential solutions associated with the District's TCP issue.

3.3.1 Cross Valley Canal

Water quality data for the Cross Valley Canal over the period of June 2010 through April 2021 is summarized in Table 3-6.

Table 3-6: Cross Valley Canal Water Quality

TCP (µg/L)	TOC (mg/L)	DBCP (µg/L)	Iron (µg/L)		Manganese (µg/L)		TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L as NO_3)	
			Min	Max	Min	Max		Min	Max	Min	Max
ND	0.526		ND	260	ND	290	2.7	6.6	140	ND	17

3.3.2 Friant Kern Canal

Water quality data for the Friant Kern Canal over the period of June 2010 through April 2021 is summarized in Table 3-7.

Table 3-7: Friant Kern Canal Water Quality

TCP (µg/L)		TOC (mg/L)	DBCP (µg/L)	Iron (µg/L)		Manganese (µg/L)		TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L)	
Min	Max			Min	Max	Min	Max		Min	Max	Min	Max
ND	0.00078	1.51	ND	ND	58	ND	13	6.2	5.2	180	ND	26

3.3.3 Kern River

Water quality data for the Kern River over the period of June 2010 through April 2021 is summarized in Table 3-8.

Table 3-8: Kern River Water Quality

TCP (µg/L)	TOC (mg/L)	DBCP (µg/L)	Iron (µg/L)		Manganese (µg/L)		TSS (mg/L)	Hardness (mg/L)		Nitrate (mg/L)	
			Min	Max	Min	Max		Min	Max	Min	Max
ND	2.2		ND	280	ND	410	5.3	19	110	ND	7.3

3.4 Intertie Pipeline Water Quality

Water quality data collected at the End-of-Canal / Intertie Pipeline is summarized in Table 3-9.

Table 3-9: Intertie Pipeline General Water Quality

Iron (µg/L)		Manganese (µg/L)		TSS (mg/L)		Hardness (mg/L)		Nitrate (mg/L)		Turbidity (NTU)	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
ND	69	ND	5.8	0.5	34	10	150	ND	19	0.79	25.8

To aid in analysis of the Intertie Pipeline treatment mitigation alternative, the TOC data collected over the most recent 12 months has been presented in Table 3-10 and turbidity and suspended solids measurements at the Intertie Pipeline have been broken down by frequency in histograms (Figures 3-1 and 3-2 respectively). It is noted that turbidities are typically significantly higher than those shown in Figure 3-1 when the District is receiving flood water, including water coming from Delta Lands Reclamation District 770. However, it has been assumed that the District would not be operating its recovery wells during these periods and therefore, treatment of such highly turbid waters would not be required.

Table 3-10: End-of-Canal TOC

Date	Total Organic Carbon (mg/L)
9/23/2020	0.839
10/27/2020	0.5
11/18/2020	0.4
12/29/2020	0.72
1/21/2021	0.5
2/18/2021	0.6
3/17/2021	0.457
4/21/2021	0.8
5/25/2021	0.7
6/23/2021	0.774
7/15/2021	0.6
8/18/2021	0.6

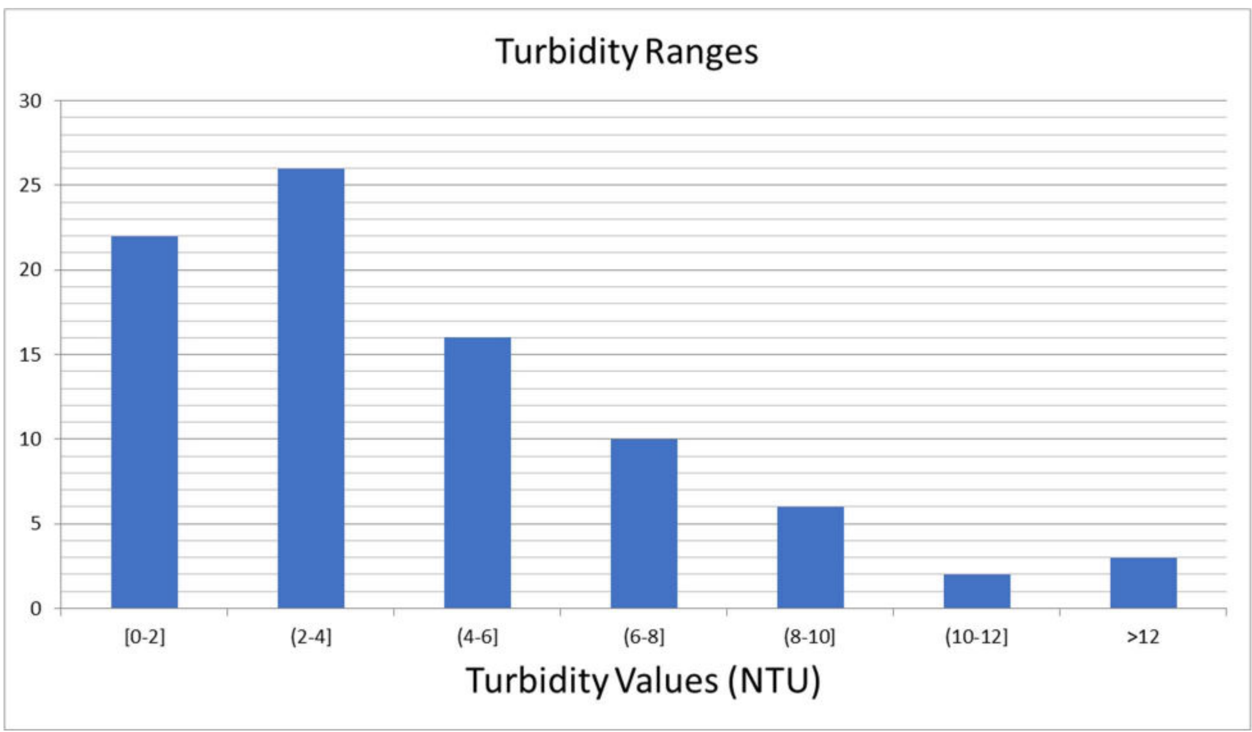


Figure 3-1: Intertie Pipeline Turbidity

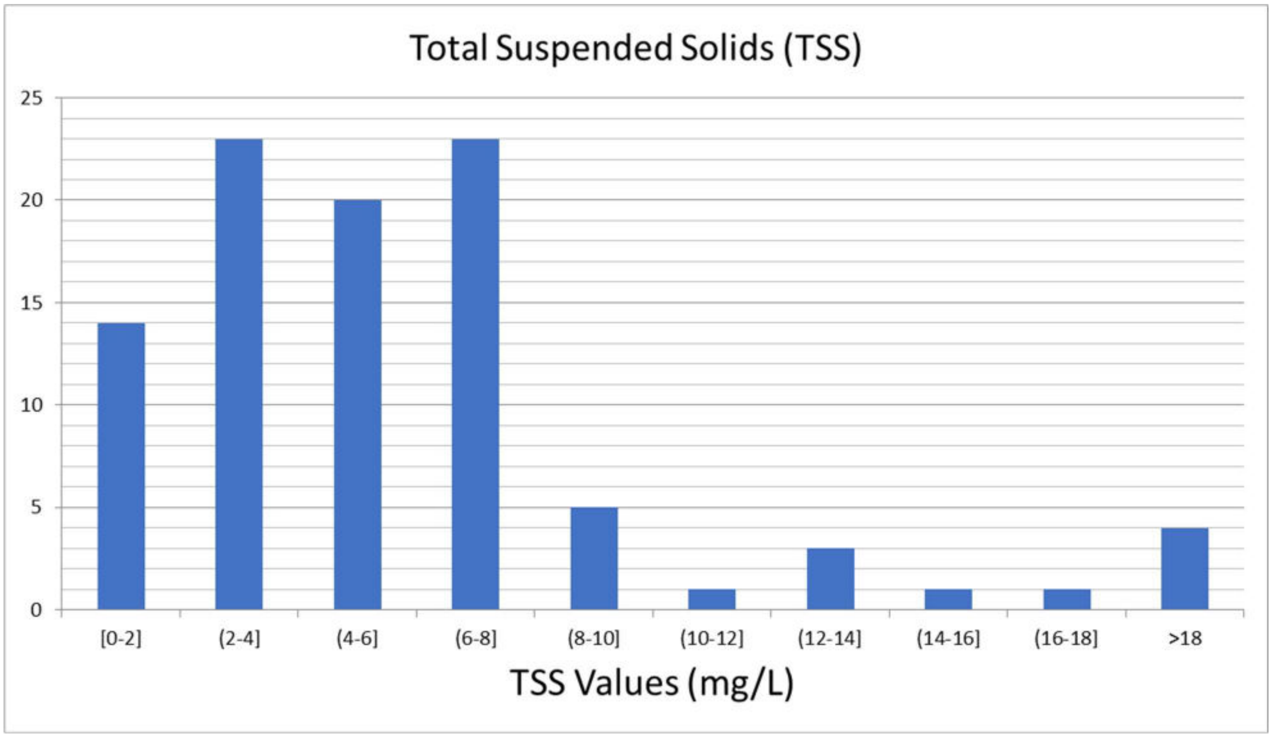


Figure 3-2: Intertie Pipeline Suspended Solids

4 MWD Program Balance and Operations

4.1 MWD Program Historical Balance

The original MWD Program agreement was signed and the first regulated water was banked in 1997. The first returned water was delivered to the California Aqueduct in 2001 via water exchange. It was not until January 2003 that the recovery wells and Intertie Pipeline were first used to return water to MWD. Over the history of the MWD Program, prior to its suspension due to the TCP contamination, the District received 719,761 acre-feet of water from MWD, of which 664,377 acre-feet was regulated in the bank (after the 10% leave behind), and 522,120 acre-feet was returned to MWD. There is currently 142,257 acre-feet stranded in the bank awaiting resolution of the TCP issue. The MWD Program historical balance is presented in Figure 4-1.

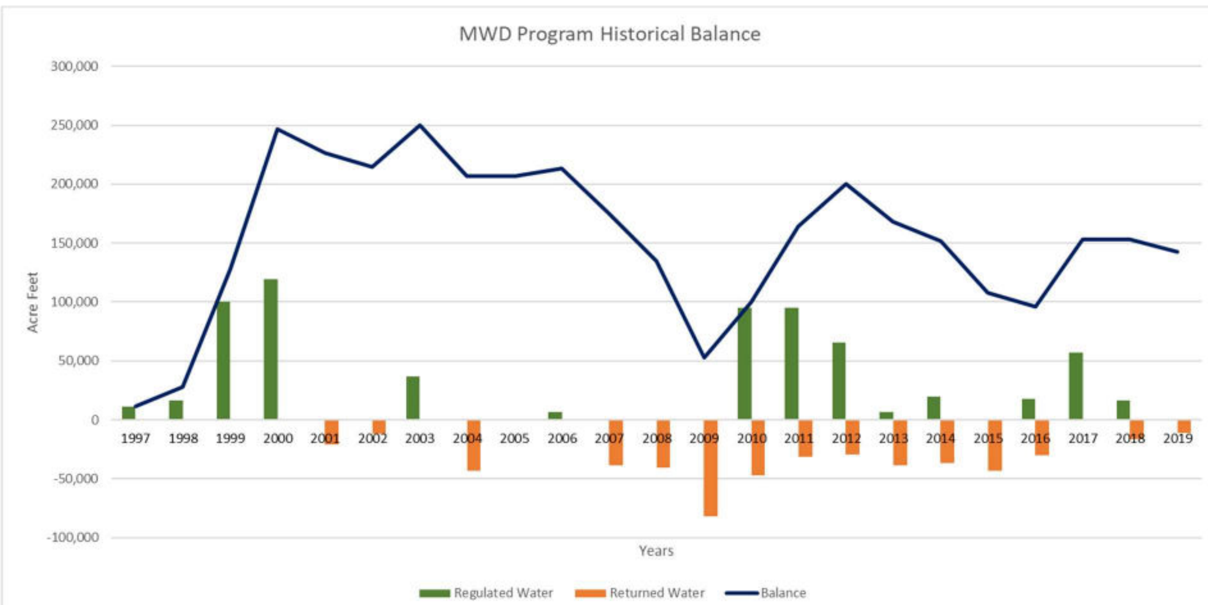


Figure 4-1: MWD Program Historical Balance

4.2 Operations Analysis

The District's water operations are very complex. Imported water deliveries and recovery well operations vary significantly from day to day. Operations involving the movement of physical "wet water" are tracked based on conveyance facility (e.g. CVC, FKC, Kern River, etc.), the agency supplying the water (e.g. CVP or SWP contractors or Kern River districts) as well as the contractual rights associated with that water (e.g. Friant Kern Class 1, Uncontrolled Class 2, etc.). Some water exchanges, including those involving the regulation and return of water as part of the MWD Program, may be paper exchanges that do not involve the transport of wet water. The chart presented in Figure 4-2 summarizes water operations for water year 2013. This figure is included to illustrate the typical complexity and day-to-day variability in District operations.

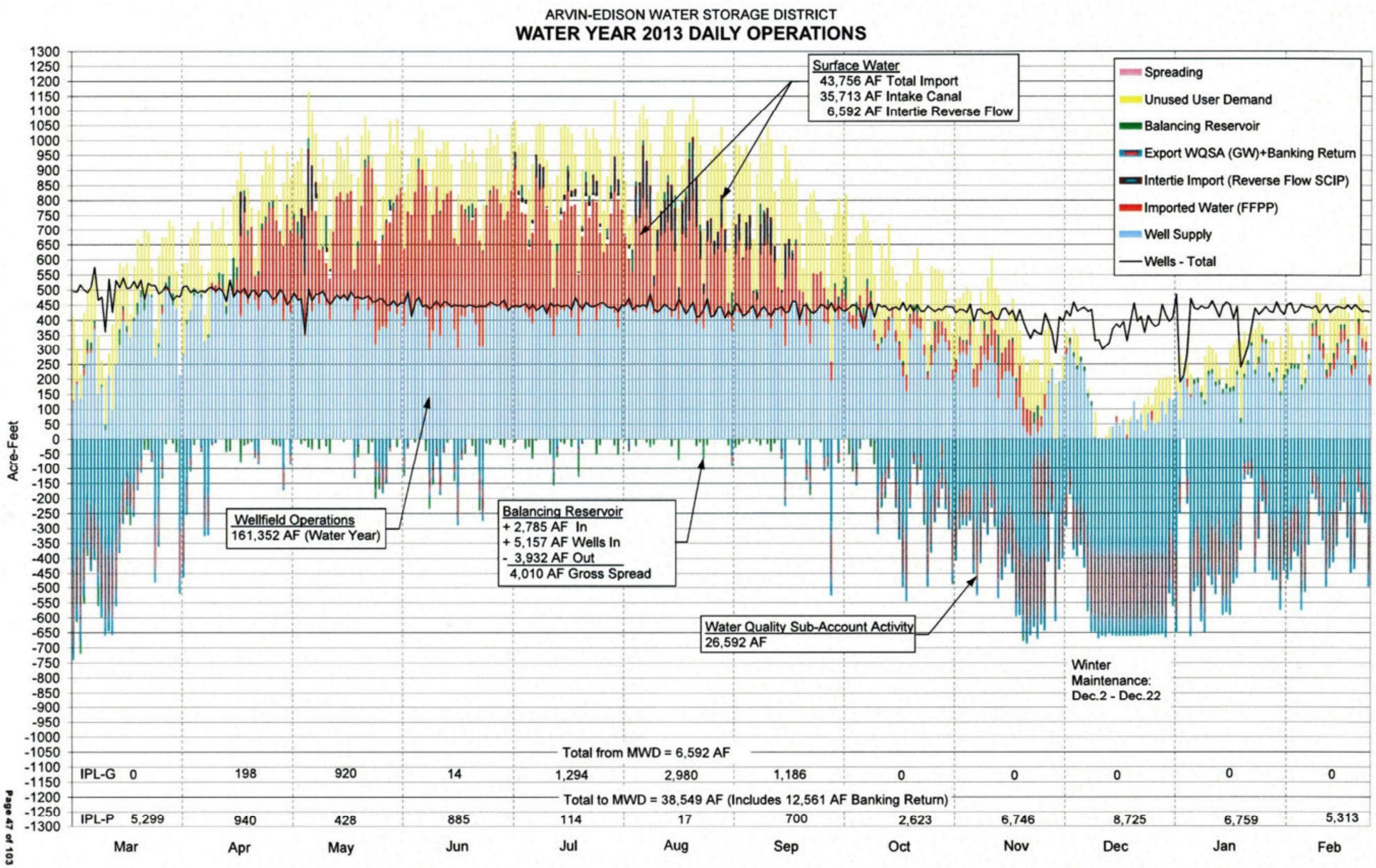


Figure 4-2: Water Year 2013 Operations Summary

The District's monthly operational records were evaluated to identify the operational patterns that are most relevant to this study. Key operational parameters for water years 2002 – 2019 are presented in Table 4-1. A more detailed monthly breakdown of these parameters is contained in **Appendix B**.

Table 4-1: Annual Water Operations Summary

Volumes in Acre Feet						
Water Year[1]	**Imported Water**	**Grower Deliveries[2]**	**MWD Deliveries (Total)[3]**	**MWD Deliveries (Intertie Pipeline)[4]**	**Recovery Well Production**	**Recovery During Months with Intertie Pipeline Deliveries[5]**
2002	99,001	148,054	11,483	11,483	80,519	14,107
2003	171,215	132,943	897	897	16,650	9,975
2004	108,504	143,662	43,277	25,512	100,125	77,485
2005	253,945	139,103	0	0	174	0
2006	219,593	134,226	0	0	1,289	0
2007	47,699	149,793	38,698	38,698	152,184	152,184
2008	63,914	149,181	40,329	40,329	139,929	139,929
2009	133,832	135,122	82,056	55,118	111,878	99,055
2010	280,394	128,235	47,367	17,701	2,723	0
2011	246,645	128,590	31,446	13,752	164	3
2012	100,170	141,637	29,614	16,738	68,699	55,360
2013	43,756	161,605	38,549	38,549	161,352	161,352
2014	45,956	127,991	36,691	52,028	134,717	134,717
2015	56,319	104,275	43,428	69,751	123,358	123,358
2016	127,552	110,679	29,999	19,489	33,010	8,602
2017	288,354	122,487	0	0	50	0
2018	149,142	118,638	16,511	13,893	18,639	2,897
2019	217,170	110,522	10,975	6,393	23	0
Total	**2,653,161**	**2,386,743**	**501,320**	**420,331**	**1,145,483**	**979,024**

[1] March 1 – February 28/29
[2] Deliveries to the District's growers. Excludes MWD deliveries.
[3] Total volume of water returned to MWD through both exchange and groundwater recovery
[4] Volume of water returned to MWD using the Intertie Pipeline only
[5] Volume of recovery well production during months when water was being delivered to the California Aqueduct via the Intertie Pipeline.

Analysis of the data reveals that:

1. Over the history of the MWD Program, 84% of the water returned to MWD has been by deliveries through the Intertie Pipeline. The remaining 16% was through water exchanges.
2. Approximately 85% of the total volume pumped by the recovery wells occurred during months when water was being delivered to MWD through the Intertie Pipeline.
3. More than half of the water recovered from the bank is delivered to the District's Growers.

4. During certain years (e.g. 2014 and 2015), deliveries through the intertie pipeline exceeded total MWD deliveries. This was due to Kern Delta supplies being wheeled from the Intake Canal through the District's system into the California Aqueduct through the Intertie Pipeline.

4.3 Maximum Flow Rates

The banking facilities have the ability to return up to 175 cfs to MWD via the Intertie Pipeline. Historically, the maximum volume the District has ever delivered through the Intertie Pipeline during a single month was 9,506-acre feet, which occurred during January 2015. This equates to an average delivery flow rate of 155 cfs over the entire month. Daily records for that month reveal a maximum daily flow rate of 170 cfs.

The maximum theoretical groundwater bank recovery capacity is approximately 288 cfs, with all 86 wells in service and pumping at the same time. The maximum volume recovered during any single month occurred during July 2001 when 16,263-acre feet was pumped. This equates to an average recovery rate of 264 cfs. More recently, in March 2013, 15,445-acre feet was pumped. This equates to an average recovery rate of 251 cfs. It is notable that the average recovery rate over the entire 2013 water year was 222 cfs, 77% of the maximum theoretical recovery rate. Pumping rates in 2021 have been as high as 261 cfs.

4.4 Projected Future Operations

District staff report that Program operations from 2002 through 2018 are anticipated to be representative of projected operations for the foreseeable future. Therefore, based on the review of data described above, the following operational assumptions have been made when evaluating potential TCP contamination mitigation alternatives:

Table 4-2: Projected Future MWD Program Operations

Parameter	Value
Maximum MWD Program delivery rate[1]	175 cfs
Maximum MWD Program annual deliveries[1]	75,000-acre feet
Average annual MWD Program deliveries[2]	28,844-acre feet
Average annual MWD Program deliveries via Intertie Pipeline[2]	24,349-acre feet
Average annual recovery well production[2]	67,380-acre feet
Average annual recovery well production during Intertie Pipeline operations[2]	57,590-acre feet

[1] Contractual
[2] Based on historical values

5 TCP Mitigation Project Design Criteria

Two alternative TCP mitigation objectives are considered in this study:

1. Mitigation of TCP contamination only in the water delivered to the California Aqueduct as part of the MWD program; and
2. Mitigation of TCP contamination in all water recovered from the groundwater bank, including water delivered to the District's growers.

5.1 Water Quality Objectives

The recovered water, at the point of delivery into the California Aqueduct, must have a TCP concentration reliably below 4 ppt (80% of the MCL value), which for practical purposes is non-detect. Additionally, for the MWD Program, the proposed solution to mitigate the TCP contamination cannot result in the increase of another Title 22 regulated contaminant or a Constituents of Concern (COC) water quality parameter that is likely to be rejected by the Non-Project Facilitation Group described in the California Department of Water Resources (DWR) *Water Policy and Implementation Process for Acceptance of Non-Project Water into the State Water Project*. Current COCs are TCP, arsenic, bromide, chloride, nitrate, sulfate, organic carbon, and total dissolved solids (TDS).

5.2 System Capacity

5.2.1 MWD Program Delivery Capacity

The District requires that the proposed solution to mitigate the TCP contamination accommodate the full MWD Program contractual delivery flow rate of 175 cfs and maximum annual delivery volume of 75,000 acre-feet.

5.2.2 Groundwater Bank Recovery Capacity

The District requires that the proposed solution to mitigate the TCP contamination accommodate operation of all recovery wells simultaneously while delivering water to MWD. This is consistent with the District's goal of being able to supply all grower water needs from the groundwater bank during critically dry years.

5.3 Design for Uncertainty in TCP Levels

Given the extent of the TCP contamination, the proposed solution must account for the likelihood that the few wells that have not yet exceeded the TCP MCL, may do so in the future under differing pumping patterns and groundwater levels.

6 Non-Treatment Alternatives

6.1 Operational Adjustments

To the extent that water can be returned to MWD through surface water exchanges instead of recovered groundwater, the impact of the TCP contamination on the MWD Program can be reduced. Such water exchanges could physically occur outside of the District's canal system and would therefore not be subject to intermingling with the TCP contaminated water pumped from the wells. The District's monthly operations records were reviewed for water years 2002 through 2019 to evaluate the feasibility of using surface water exchanges to avoid using the Intertie Pipeline. As expected, the availability of imported surface water is generally inversely related to the need to return water to MWD. The need to utilize the Intertie Pipeline was therefore unavoidable during most periods when MWD water was being returned. However, there were a few periods, most notably during water years 2014 and 2015, during the peak of the extreme drought, when the Intertie Pipeline was used to deliver water to MWD despite there apparently being an equal or greater volume of imported water (typically from the FKC) available.

In total, it appears that it was theoretically possible to have supplied as much as 178,279-acre feet of the total 501,320 acre feet that has been delivered to MWD (35% of the total) by surface water exchange. However, as a practical matter, the amount of Intertie Pipeline water that could have been offset by water exchange is likely much less due to the following factors:

1. The District has limited capacity to convey recovered groundwater to the northern portion of its service area and must therefore accept the surface water deliveries to serve its northern SWSA growers.
2. The granularity of the monthly data does not capture the day-to-day variability in imported water supplies that is reflected in Figure 4-2. During the months under consideration, it is likely that daily imported water supply and MWD delivery requirements were not consistently compatible.
3. It is unlikely the availability of the imported water would have been known with enough lead time to make the necessary adjustments in groundwater bank recovery operations.
4. There are practical limitations on how frequently the District can make adjustments to imported water orders and recovery well operations. The District's 86 recovery wells are operated manually and typically left in an "off" or "run" state for several months at a time.
5. These exchanges will be subject to the operational constraints of the CVC.

For these reasons, operational changes are unlikely to result in significant mitigation of the TCP issue.

6.2 Wheeler Ridge Water Exchanges

The previous section considered operational adjustments that could potentially be made using existing infrastructure. This section evaluates a more specific alternative that would necessitate the construction of additional infrastructure to enable water exchanges with Wheeler Ridge – Maricopa Water Storage District (WRMWSD). WRMWSD is a Kern County water district with an approximately 147,000-acre service area that partially overlaps with the southernmost portion of Arvin-Edison's service area. Nearly all of the surface water entering WRMWSD is State Water Project water conveyed through the California Aqueduct.

An intertie between the District's South Canal and the Wheeler Ridge WRMWSD's 850 canal was contemplated. Under this concept, MWD's banked water that they call on to be returned would be delivered to WRMWSD. WRMWSD would then exchange a like amount of their SWP supplies to MWD. In the initial review of the alternative several major issues were identified. First, the alternative assumes WRMWSD would approve of the project and the exchange, and in effect adds a third party to the AEWSD/MWD banking program. Second, the canals are nearly 5 miles apart with about 360 feet of elevation difference. An additional 45 feet of lift would be required for friction losses, requiring a total of 405 feet of lift. The motors to drive the pumps for this project would need to produce approximately 11,000 hp in order to deliver the 175 cfs flow to WRMWSD. Third, this concept assumes that in dry years when MWD would need to recover water from the bank, that WRMWSD would have a like amount of water to actually exchange, which is highly uncertain given the current pumping restrictions in the SWP. For these reasons, the concept was determined not to warrant further analysis.

6.3 Well Replacement

The very characteristics that make the District's spreading works effective for groundwater banking makes the bank susceptible to land-applied contaminants such as TCP. The aquifer underlying the District has no laterally continuous regional clay layer such as the Corcoran Clay that exists further north in the Central Valley. The local discontinuous interfingered clays allow TCP to migrate deeper into the aquifer and prevents wells from being constructed deep enough to avoid the TCP. One further complication with constructing deeper wells is that arsenic levels tend to rise in the deeper formations. Arsenic is a MWD Program COC. Arsenic is a more severe problem in the northern part of the District where TCP concentrations are also highest. Another complication with constructing deeper wells is the increased risk of land subsidence.

There is significant evidence that construction of replacement wells is unlikely to successfully mitigate the TCP contamination. Specifically:

1. The District currently has 86 wells located along an approximately 20-mile alignment that traverses a large portion of the District's service area. The TCP concentrations trend downward the further south the wells are located, however, almost all of the wells, even in the southernmost Tejon spreading works, have TCP concentrations several times the MCL value.
2. Many of the District's wells are located near the edge of the foothills on the upgradient edge of the farmland where the TCP-contaminated soil fumigants were applied.
3. The District has in recent years constructed wells with deeper sanitary seals ranging from 200 to 312 feet deep. Out of seven wells constructed with sanitary seals 200 feet deep or deeper, five have had detections of TCP over the MCL.
4. Both the City of Bakersfield and the town of Mettler, which lie west of the District's northwestern and southwestern boundaries respectively, have extensive TCP contamination of their wells. The town of Arvin located near the center of the District also has TCP contaminated wells.

6.4 Blending

For blending to be a feasible mitigation strategy, there must be a source of dilution water available that is not contaminated with TCP. The dilution water must also be available at the same time that recovery from the groundwater bank is occurring. Three potential blending scenarios were considered: inter-well blending, blending with imported surface water within the District's transmission canals, and in-prism blending within the California Aqueduct.

6.4.1 Inter-Well Blending

If enough recovery wells reliably had non-detect or very low concentrations of TCP, those wells could be blended with contaminated wells to reduce the TCP concentration of the water before it is discharged into the North and South canals.

Among the recovery wells that have been tested for TCP, only 9 of the 86 wells have not yet had a TCP detection and only 15 of the 86 wells, including the non-detect wells, have remained consistently below ½ of the MCL (<3 ppt). No parameter such as spatial location or well depth has been identified to explain why those particular wells have lower concentrations of TCP compared to the other wells. Many of the wells, particularly those located further to the north, contain TCP at concentrations more than 25 times the MCL. Blending down the water from just one of the North Canal wells could not be accomplished even with the combined flow from all the 15 wells that have been consistently below ½ of the MCL. Furthermore, it is noted that the concentration of TCP in most of the wells varies greatly between samples. For several of the wells TCP concentrations have varied by a factor of 2 or 3. This is true even among the wells with lower concentrations. For example, the levels of TCP at Sycamore Well 4 were non-detect the first two times it was tested during the 2nd quarter of 2018 and the 1st quarter of 2019, but then unexpectedly rose to 14 ppt (almost three times the MCL) during the 2nd quarter of 2020. High variability in TCP concentrations is something that has been observed in many areas of the Central Valley.

Given the small number of wells that have yet to exceed the TCP MCL and the variability in TCP concentrations among wells with both low and high TCP concentrations, inter-well blending is not a feasible mitigation strategy, either as a complete solution or as a partial solution.

6.4.2 Blending with Imported Supplies

The District has rights to Class 1 and Class 2 surface water from the FKC and water from the Kern River. In theory, blending of these imported surface water supplies with groundwater from recovery wells might be used to reduce the TCP concentration below the MCL. However; such an approach is impractical for at least two reasons:

1. As noted previously, there is an inverse relationship between the availability of surface water and the need to recovery water from the bank. A review of the District's annual operations reports demonstrates that the volume of imported water entering the canal system is not great enough during periods when the recovery wells are in operation to reduce the TCP levels to below the MCL value.
2. Many of the wells, particularly those further to the north, have very high TCP concentrations. The average TCP concentration in the North Canal wells is greater than 25 times the MCL value. Blending down the TCP concentration of the water produced by the North Canal wells to below 5 ppt would require a volume of imported water 24 times the volume produced by the wells, which is clearly infeasible.
3. Even if greater volumes of imported water were available, the physical configuration of the District's canal transmission system, which typically flows from north to south, but is occasionally pumped in the opposite direction, would make management of such a blending program impractical. The District would need to monitor, track, and carefully regulate the operation of every recovery well and grower turnout along each reach of the canals to ensure that the blend ratio remained acceptable as water made its way to the Intertie Pipeline.

6.4.3 Aqueduct In-Prism Blending

As described in the Arvin-Edison Water Storage District Aqueduct Pump-in Proposal, "It is the quality of the water at the End-of-Canal (California Aqueduct turnout) that is of interest to DWR and the stakeholders." No provisions are included in the Pump-in Proposal for in-prism blending within the California Aqueduct. The DWR Policy for Acceptance of Non-Project Water into the State Water Project states that future projects "…involving water quality exceeding primary drinking water standards shall show that the water shall be treated or blended before it enters the SWP to prevent water quality impacts." and "…shall be managed and operated such that poor quality water will be blended with better quality water so that SWP water quality will not be degraded…" MWD has a policy of not allowing the California Aqueduct to be a source of blending dilution water and has suspended the program until the TCP contamination can be mitigated prior to the water entering the California Aqueduct.

7 Treatment Alternatives

7.1 Treatment Process Alternatives

Treatment process alternatives including air stripping, reverse osmosis, advanced oxidation, sorbents, biological treatment, and granular activated carbon (GAC) have all been investigated for TCP removal treatment. The only two treatment technologies that are viable are GAC and engineered biological treatment. All municipal TCP removal water treatment plants utilize GAC due to its simplicity, reliability, and relative cost effectiveness. Engineered biological treatment utilizing the patented biologically-tailored, two-stage treatment approach (biottta®) process has been demonstrated to be effective for reduction of TCP in pilot studies and at one full-scale wellhead treatment plant. However; even though there are unlikely to be any concerns with discharge of biologically treated water into the California Aqueduct, the biottta process is operationally complex and, where only TCP needs to be removed from the water, is not expected to offer any cost savings compared to GAC. Only the GAC treatment process has been considered further.

7.2 Project-Specific Treatment Design Considerations

The District's situation is unique compared to the many municipal TCP mitigation projects that have been completed or are underway. Unlike municipal drinking water treatment systems, the water the District delivers to the California Aqueduct and its growers does not need to meet the drinking water standards for turbidity or bacteriological quality. The most significant consequence of this is that the District can consider the use of gravity contactors that are open to the air. This is not practical for municipal systems because, once the water is exposed to the elements, it would then need to be treated to stringent surface water treatment standards before it enters a drinking water system. The lack of a bacteriological standard should also simplify operation of the proposed treatment plant(s) in that intermittent operation of the GAC systems, which can lead to bacteriological growth on the carbon, may be simplified.

Gravity GAC contactors are used at municipal surface water treatment plants. However, application of gravity GAC to the District's situation is also unique compared to municipal gravity surface water GAC treatment plants in that the water in the District's canals contains significant concentrations of solids (e.g. silt, debris, and algae), but there is no requirement to remove any of these solids. Ideally, the system would be designed to allow all of the solids to pass through the treatment plant to reduce the need for carbon backwashing.

Conversely, it is also important to note that the finished water TCP objective for the District is no different from a municipal water treatment project. DWR and the Non-Project Facilitation Group require the selected mitigation approach to reliably reduce the TCP entering the California Aqueduct to be below the MCL. There is no indication that operating the proposed treatment system to a looser standard will be accepted.

Three GAC treatment alternatives have been evaluated:

1. Traditional wellhead treatment at the recovery wells using pressure vessels;
2. Centralized gravity adsorbers at each of the spreading basins with wellhead treatment for five of the more remote North Canal wells; and
3. A single gravity filter/adsorber near the Intertie Pump Station

Each of the alternatives are described in more detail in a subsequent report section.

7.3 Alternative 1: Wellhead Treatment

This alternative would consist of installing pressure-vessel based treatment plants at the recovery wells – an approach that has been successfully used for many municipal wells throughout the state. It has been assumed that wells with TCP concentrations that have not yet exceeded ½ of the MCL (18 wells) will not be treated. Many of the recovery wells at the spreading basins are already manifolded together upstream of their point of discharge into the canal. The 86 wells are manifolded into 40 discharge points. Consolidating wellhead treatment into semi-centralized plants treating the water after the wells are manifolded together would reduce the number of treatment plants by almost 30%, which would result in reduction in both capital and O&M costs. The alternative of further manifolding the wells together and constructing a single centralized treatment plant utilizing pressure vessels at each of the spreading works was also evaluated to provide a baseline for comparison with the gravity adsorber alternative.

Advantages	Disadvantages
• Provides the capability of treating the water delivered to the District's growers. • Does not treat water from wells with TCP below the MCL • Treating high-TOC surface water is avoided. • Filtration of surface water is avoided. • Lower carbon usage rates than the other two alternatives	• Higher capital cost compared to the other alternatives • The large number of vessel systems required would result in increased administrative complexity and more-or-less continuous maintenance activities. • The steel pressure vessels require more maintenance than gravity systems constructed primarily of concrete. • Treatment system head loss will impact recovery well production capacity • Loss of spreading basin area due to treatment plant footprints

7.3.1 Wellhead GAC Design Parameters

The primary parameters driving the design of the wellhead GAC treatment process are empty bed contact time (EBCT), hydraulic loading rate (HLR), and whether vessels are operated in a single-stage configuration or with multiple vessels in series (lead-lag).

<u>Empty Bed Contact Time</u>
The adsorption process is dynamic – requiring time during which the water is in contact with the carbon for complete removal of TCP to take place. The parameter used to describe the contact time is the empty bed contact time (EBCT), which is calculated by dividing the volume occupied by the carbon by the flow rate. A total EBCT of 15 minutes is typically recommended to accommodate TCP's relatively long adsorption mass transfer zone and the low treated water TCP objective.

<u>Hydraulic Loading Rate</u>
The hydraulic loading rate (HLR) is calculated by dividing the flow, in gpm, by the cross-sectional area of the vessel or gravity bed. Higher HLR values result in greater pressure loss across the treatment system and can

lead to short circuiting (channeling) of TCP through the bed. For pressure vessel systems HLR values below 6 gpm/ft^2 are recommended with 8 gpm/ft^2 being an upper limit for system sizing.

Series / Single-Stage Operation

For a given EBCT, there are two ways to operate pressure vessel systems: with single-stage vessels or with pairs of vessels arranged in series. With single-stage operation, the water being treated flows through only one GAC vessel. With series operation, the water will flow through one vessel (the lead vessel) and then through a second vessel (the lag vessel) before leaving the treatment plant. The primary disadvantage of operating the vessels in a series configuration is that it increases the pressure drop across the treatment system. The primary advantages of operating with pairs of vessels in series are:

- The carbon in the lead vessel can be more completely utilized before it must be changed out. For single-stage operation, the carbon in the vessels must be changed out while there is significant carbon adsorption capacity remaining.
- The carbon in the lag vessel acts as a safety buffer that should capture any TCP that unexpectedly makes it past the lead vessel. Unexpected breakthrough from the lead vessel might occur after hydraulic transients; following maintenance backwashing; after the system has been off-line for an extended period; due to channeling through the bed; or due to desorption of TCP from the carbon caused by changing raw-water TCP concentrations.
- The carbon in the lead vessel can be changed out while the well is still in operation and is being treated through the lag vessel. Typically, for municipal systems, the well must be taken out of service to change out carbon when operating in a single-stage configuration.

For the above reasons, a series vessel arrangement should be used.

7.3.2 System Description

As noted above, some of the District's wells are already manifolded together prior to discharging into the transmission canal system. It is more efficient to treat the grouped wells together instead of constructing individual wellhead treatment plants. The proposed wellhead treatment plant well groupings, capacities, and vessel counts are summarized in Table 7-1. Treatment plants identified with shaded cells have been reduced in capacity where some of the wells supplying the plant are below ½ of the TCP MCL and eliminated entirely if all wells supplying the plant are currently below ½ of the MCL. A total of 40 treatment plants are required to treat 68 out of the District's 86 existing wells. Twelve (12) foot diameter vessels have been assumed. This is the practical upper limit to pressure vessel size before transport of oversized loads becomes problematic.

Table 7-1: Wellhead Treatment Plant Groupings

Wellfield	Plant	Wells	Combined Capacity (cfs)	Combined Capacity (gpm)	12-Foot Diameter Vessels
North Canal	~~NP1~~	~~N15, N16, N17, N18~~	0.00	0	0
	NP2	N1	3.32	1,490	6
	NP3	N2	3.20	1,440	6
	NP4	N3	3.78	1,700	6
	NP5	N4	3.41	1,530	6
	NP6	N5	3.79	1,700	6
	NP7	N6, N7, N14	9.97	4,480	14
	NP8	N8, N9, N10, N11, N12	16.25	7,290	22
	NP9	N13	2.87	1,290	4

Wellfield	Plant	Wells	Combined Capacity (cfs)	Combined Capacity (gpm)	12-Foot Diameter Vessels
	NP10	N19	7.15	3,210	10
	NP11	N20	7.34	3,290	10
	NP12	N21	7.44	3,340	10
	NP13	N22	7.28	3,270	10
	NP14	N23	7.28	3,270	10
Sycamore	~~SP1~~	~~38~~	0.00	0	0
	SP2	~~35~~, 36, 37	5.92	2,656	8
	SP3	31, ~~32, 33~~, 34	4.89	2,195	8
	~~SP4~~	~~16~~	0.00	0	0
	SP5	~~17, 18,~~ 28, ~~29~~	4.05	1,816	6
	~~SP6~~	~~15~~	0.00	0	0
	SP7	13, 14, 25, 26	12.34	5,540	16
	SP8	12	3.54	1,590	6
	SP9	10, 11, 23, 24	14.61	6,560	20
	SP10	9	2.71	1,220	4
	SP11	8	3.52	1,580	6
	SP12	6, 7, 22	10.20	4,580	14
	SP13	4	3.60	1,610	6
	SP14	1, 2, 5, 20, 21	15.44	6,930	20
Tejon	TP1	99	5.70	2,560	8
	TP2	~~78,~~ 79, 84	6.03	2,704	8
	TP3	73	3.38	1,520	6
	TP4	~~77, 81,~~ 82, ~~83~~	3.22	1,445	0
	TP5	98	5.94	2,670	8
	TP6	72	3.19	1,430	6
	TP7	92, 93, 94, 95, 96	15.06	6,760	20
	TP8	76	2.79	1,250	4
	TP9	71	2.85	1,280	4
	TP10	~~74~~, 75, 80	4.86	2,180	8
	TP11	90, 91	5.35	2,400	8
	TP12	86	2.83	1,270	4
	TP13	87	2.64	1,180	4
	TP14	89	1.83	820	4
	TP15	88	2.82	1,270	4
	TP16	100, 101	13.86	6,220	18
		Total	**246.3**	**110,500**	**352**

If the wells were fully manifolded together at each of the spreading works, the number of 12-foot diameter vessels required to provide 15 minutes of EBCT could be reduced from 352 to 320 (114, 102, and 104 at the North Canal, Sycamore, and Tejon spreading works respectively). This assumes that the five wells along the

North Canal alignment (N1 through N5) are treated independently. Much of the potential cost savings resulting from a reduction in the number of vessels would be offset by the cost of additional pipe manifolds. An additional five treatment plants incorporating 24 vessels would be required to treat the grower in lieu wells.

A typical wellhead treatment plant has been shown in Figure 7-1.

Figure 7-1: Typical GAC Wellhead Treatment Plant

7.3.3 Backwash Management

All GAC treatment systems, whether pressure vessel systems or gravity systems, must be backwashed for carbon conditioning after each delivery of carbon. Soaking and backwashing newly installed carbon accomplishes the following:

- Removes trapped air from the internal carbon pores and between particles;
- Sweeps the resulting air from the carbon bed;
- Removes carbon fines generated due to physical abrasion during transport.
- Stratifies the media bed so that subsequent backwashing is less likely to disrupt treatment performance; and
- Flushes water soluble activation byproducts (e.g. ash) from the carbon.

Typically, the carbon is soaked in water for 16 – 24 hours prior to the initial backwashing. Backwash flow rates will vary depending on the bed area, GAC type and density, and the temperature of the water. The maximum backwash flow rate for a 12-foot diameter pressure vessel is as high as 1,500 gpm. Over a 30-minute backwash, approximately 45,000 gallons could be used.

Backwashing may also be required if the head loss through the treatment system builds up to an unacceptable level over time. This might result if the well water contains sand or other suspended solids that would accumulate on the carbon bed. A typical "maintenance" backwash criterion is to backwash the vessels when the head loss rises to between 10 and 15 psi. However; backwashing after the initial carbon load should occur sparingly since re-stratifying the bed will disrupt the adsorption mass transfer zone and result in reduced carbon life.

For most municipal systems, water for backwashing is supplied from the pressurized water distribution system, including any water being produced by GAC vessels that are still on-line. In this case, there is no pressurized water distribution system. However, given the number of vessel pairs involved, it appears feasible to supply backwash water from the remaining on-line GAC systems provided the treatment plant is designed to generate sufficient backpressure in the treated water manifold. Raw well water will need to be used for backwashing during initial startup with the consequence that some TCP leakage may occur after the systems first start treating water.

Spent backwash water contains carbon fines and TCP concentrations likely similar to the raw water concentrations. Since there are no waters of the United States in proximity to the spreading works and Intertie Pipeline, it is anticipated that backwash water can be discharged to land. Regional Water Quality Control Board Resolution R5-2018-0085 establishes a Waste Discharge Requirements waiver process specific to these types of treatment plants. The District would need to submit a Report of Waste Discharge requesting the waiver. Given the hundreds of acres of spreading works ponds that would be adjacent to the treatment plants, the ponds would be the most economical location to discharge the backwash water. This would allow the District to conserve the water used for backwashing by recharging it and would contribute an insignificant solids loading to the ponds compared to the suspended solids present in the imported surface water supplies.

7.3.4 Pump Lubrication

The District's recovery well pumps are all oil lubricated. Oil lubricated well pumps can create problems with downstream GAC treatment processes if the layer of oil that accumulates in the well casing is pumped out. The organic oil will foul the GAC and can dramatically impact carbon usage rates. For most municipal GAC wellhead treatment applications, the wells are converted to water lubrication to eliminate this risk. However, the static depth to water at the District's wells, which exceeds 400 feet in some wells, precludes conversion of the pumps to water lubrication due to concerns with the ability to reliably wet the bearings over that depth. Instead, the District will need to mitigate the risk of oil fouling by carefully monitoring pumping water levels relative to pump bowl settings and by bailing out the accumulated oil whenever the pumps are pulled for maintenance.

7.3.5 Carbon Replacement

Activated carbon has a finite capacity for removing the target contaminant. This capacity is typically described in terms of pounds of carbon used per 1,000 gallons treated. 1 pound per 1,000 gallons treated is equivalent to 325 pounds per acre foot treated. The carbon capacity realized at a particular treatment plant depends on many factors, including:

- The GAC product used. Carbon is manufactured from different base materials including coal and coconut shells. The activation process also varies from supplier to supplier.
- The concentration of the target contaminant in the raw water – TCP in this case.
- The treatment objective – TCP reduced to non-detect in this case.

- The concentration of background organic materials in the water. The District's well water contains concentrations of naturally occurring organic compounds that range between 0.15 and 0.75 mg/L – concentrations four orders of magnitude greater than the concentration of TCP. These organic compounds will be adsorbed by the carbon and use up capacity that would otherwise be available for adsorption of TCP. The background TOC generally impacts the carbon life more than the water's TCP concentration.
- The presence of inorganic contaminants in the water, particularly iron and manganese, that will tend to foul the carbon and reduce its adsorption capacity.

When a bed of carbon is no longer capable of meeting the treatment objective, it must be replaced with new "virgin" carbon or the used carbon can be sent off-site for reactivation and returned by the supplier to the treatment plant. The decision whether to use virgin or reactivated carbon is based on the relative cost and treatment performance.

The carbon usage rate data available from full-scale systems treating for TCP removal spans a broad range of values. Results as low as 0.083 lbs./1,000 gallons and as high as 1.2 lbs./1,000 gallons have been documented. It is noted that the wells representing the upper end of this carbon usage range are believed to produce water containing manganese or iron that may be fouling the carbon. Statewide average carbon usage rates are approximately 0.13 lbs/1,000 gallons.

7.3.6 Carbon Handling

Carbon is typically replaced by slurry transfer from 65' tractor trailers. The trailers can haul up to 40,000 pounds of carbon per load for initial loading of the vessels. When carbon already installed in the vessels is being changed out, the delivery truck shows up to the site with approximately 20,000-lbs of carbon and an empty compartment. The used carbon is first transferred into the empty compartment and then the replacement carbon is transferred into the now-empty treatment vessel.

7.3.7 Impact of Treatment on Well Capacity

Placing treatment plants between the wells and canal will result in additional backpressure on the well pumps and a corresponding reduction in well production. The pressure loss across a GAC treatment plant with pairs of vessels operated in series is approximately 10 psi (23 feet of water). Pump curves for typical 300 and 600 horsepower (HP) recovery well pumps were evaluated to estimate the resulting loss in well production (refer to **Appendix C**). The estimated loss in production from each of the 300 and 600 Hp pumps would be 0.22 cfs (100 gpm) and 0.39 cfs (175 gpm) respectively. Assuming that the average reduction in flow for these two well pump models is representative of all the well pumps currently installed, the overall impact to supply capacity resulting from treating 68 of the 86 existing wells would be approximately 21 cfs.

To mitigate the overall loss in pumping capacity, the District would either need to replace the pumps and potentially the motors and motor starters to support higher discharge heads, or new recovery wells would need to be constructed to make up for the loss in capacity. For the purpose of this evaluation, it has been assumed that the District would construct new recovery wells. The average capacity of the District's existing 86 recovery wells is approximately 3.3 cfs. It has therefore been assumed that seven (7) new wells will need to be drilled and equipped to make up for the 21 cfs loss in well capacity. Since, due to system hydraulics and water demand, the District will need to construct new wells in the northern portion of the system where TCP levels are highest, it has also been assumed that these 7 new wells will be contaminated with TCP and require treatment.

7.3.8 Treatment System Hibernation

MWD does not call for banked water to be returned every year and during years when water is returned, it may not be during all months. Therefore, the treatment plants will need to remain off-line for extended periods of time. In a municipal setting, the biggest challenge with this type of start and stop operation is the potential for bacteria (coliform typically) to grow on the carbon and for the treated water to not meet drinking water bacteriological standards. This is not a concern in this case. Whenever it is expected that the treatment plants will be off-line for an extended period of time, the vessels will need to be dewatered and the isolation valves closed. Backwashing of the vessels may be required when they are brought back on-line. A similar approach will work for the gravity systems described in Alternatives 2 and 3.

7.3.9 Other Hydraulic Considerations

It is important that the GAC systems not be dewatered when the recovery wells are intermittently started and stopped. This is for several reasons including avoiding air binding in the bed and avoiding disruption to the bed caused by cascading water. The GAC vessels are approximately 17 feet tall and they will be discharging into a canal located below the elevation of their foundation. Without special provisions, the vessels will dewater into the canal when the wells are shut off. To avoid this, the system(s) will need to discharge into an elevated pipe loop with an anti-siphon valve at the top, a standpipe with an overflow weir, or equivalent. It is acceptable and necessary to dewater the GAC systems during extended periods of non-operation such as might occur during wet years.

7.4 Alternative 2: Centralized Treatment at Spreading Works

Even though wellhead GAC treatment utilizing steel pressure vessels has been used at most, if not all, municipal TCP-removal GAC treatment plants, that approach may not be the most efficient for resolving the District's TCP problem. Given the magnitude of the flow rates involved and the unique aspects of the District's situation described in Section 7.2, gravity treatment systems constructed of cast-in-place concrete should be considered. This alternative would consist of constructing a single centralized gravity adsorber system at each of the three spreading works (North Canal, Sycamore, and Tejon). Because the North Canal wells N-1 through N-5 are located a significant distance away from the North Canal Spreading Works, it has been assumed that these wells would be treated using the more conventional pressure vessel systems – five individual systems for wells N-1 through N-5.

Gravity GAC treatment systems can be divided into two categories: filter adsorbers and contactors. Filter adsorbers are designed to provide filtration for solids removal as well as adsorption. Contactors are designed for adsorption only. For this alternative, only well water would be treated. The available data indicates that the well water is relatively low in suspended solids (e.g. sand) and therefore backwashing would be mostly limited to that required after installation of new carbon with the potential for occasional maintenance backwashes. Therefore, gravity contactors not designed for filtration have been assumed.

Advantages	Disadvantages
• Provides the capability of treating the water delivered to the District's growers. • Does not treat water from wells with TCP below the MCL • Treating high-TOC surface water is avoided. • Filtration of the water is avoided. • Lower carbon usage rates than centralized treatment at the Intertie Pipeline • Fewer facilities to operate and maintain compared to the wellhead treatment alternative	• Loss of spreading basin area • Treatment system head loss will impact well production capacity. • Higher carbon usage than the wellhead treatment alternative.

7.4.1 GAC Design Parameters and System Description

The GAC design parameters used for a gravity contactor system differ from those used for a traditional pressure vessel wellhead treatment system. One key difference is that operation of a gravity system with beds in a series arrangement is impractical. Once the well pumps break head to atmospheric pressure at the inlet to the gravity contactor, there is no easy way to convey that water to a second contactor. The water would either need to be re-pumped or the overall facility constructed high enough above the canal that the lower gullet of the first stage contactor could serve as the upper gullet of the second stage contactor. Both options would significantly increase system cost and complexity. The lack of series beds is expected to increase carbon usage rates compared to the wellhead treatment alternative.

It is common to design GAC filter adsorbers with an underlayer consisting of approximately 1 foot of sand. Since filtration is not an objective of this project, it has been assumed that GAC mono-media without a sand layer will be used. An underdrain system capable of handling carbon fines, such as a wedge wire system, will need to be used. Non-filtering gravity contactors typically operate at bed depths ranging from 8 – 12 feet. A 10-foot deep bed has been assumed. Hydraulic loading rates for gravity contactors typically range from 4 to 8 gpm/ft^2. A value of 6 gpm/ft^2 has been assumed. This combination of 10-foot bed depth and 6 gpm/ft^2 hydraulic loading rate results in an EBCT of 12.5 minutes.

Using the above parameters and assuming treatment of the same wells identified in Section 7.3.2 results in the following preliminary system sizing:

Table 7-2: Treatment Alternative 2 Process Parameters

Parameter	North Canal	Sycamore	Tejon
Flow Rate (cfs)	66[1]	81	82
Flow Rate (gpm)	29,430[1]	36,300	36,960
EBCT (minutes)	12.5	12.5	12.5
HLR (gpm/ft^2)	6.0	6.0	6.0
Number of Cells	10	10	10
Number of Cells (During backwash and change-out)	9	9	9
Filter Area -Total (ft^2)	4,900	6,050	6,160
Filter Area - Per Cell (ft^2)	490	605	616
GAC depth (ft)	10	10	10
Approx. Carbon Capacity – Total (lbs)	1,378,000	1,701,000	1,723,000
Approx. Carbon Capacity – Cell (lbs)	137,000	170,000	172,000
Backwash Rate (gpm/ft^2)	14	14	14
Backwash Flow Rate (gpm)	6,860	8,470	8,624
Approximate Filter Dimensions (ft)	14 x 35	16 x 39	16 x 39
Approximate facility site footprint (acres)	0.75	1	1

[1] Assumes 5 wells along canal alignment are treated at stand-alone wellhead treatment plants.

The size of the contactor structure would be approximately three times the filter area. However, additional space will be required for inlet and outlet pipelines, carbon delivery truck access, a control building, etc. The estimated height of the contactor structures is approximately 30 feet.

Similar to the wellhead treatment alternative, the treatment plants will need to be designed to prevent dewatering of the GAC system. A seal well incorporating an overflow weir can be used for this purpose.

A typical GAC gravity contactor is shown in Figure 7-2. Preliminary treatment plant locations and proposed manifold piping networks for the North Canal, Sycamore, and Tejon treatment plants are illustrated in Figures 7-3, 7-4, and 7-5 respectively.

Figure 7-2: Typical GAC Gravity Contactor

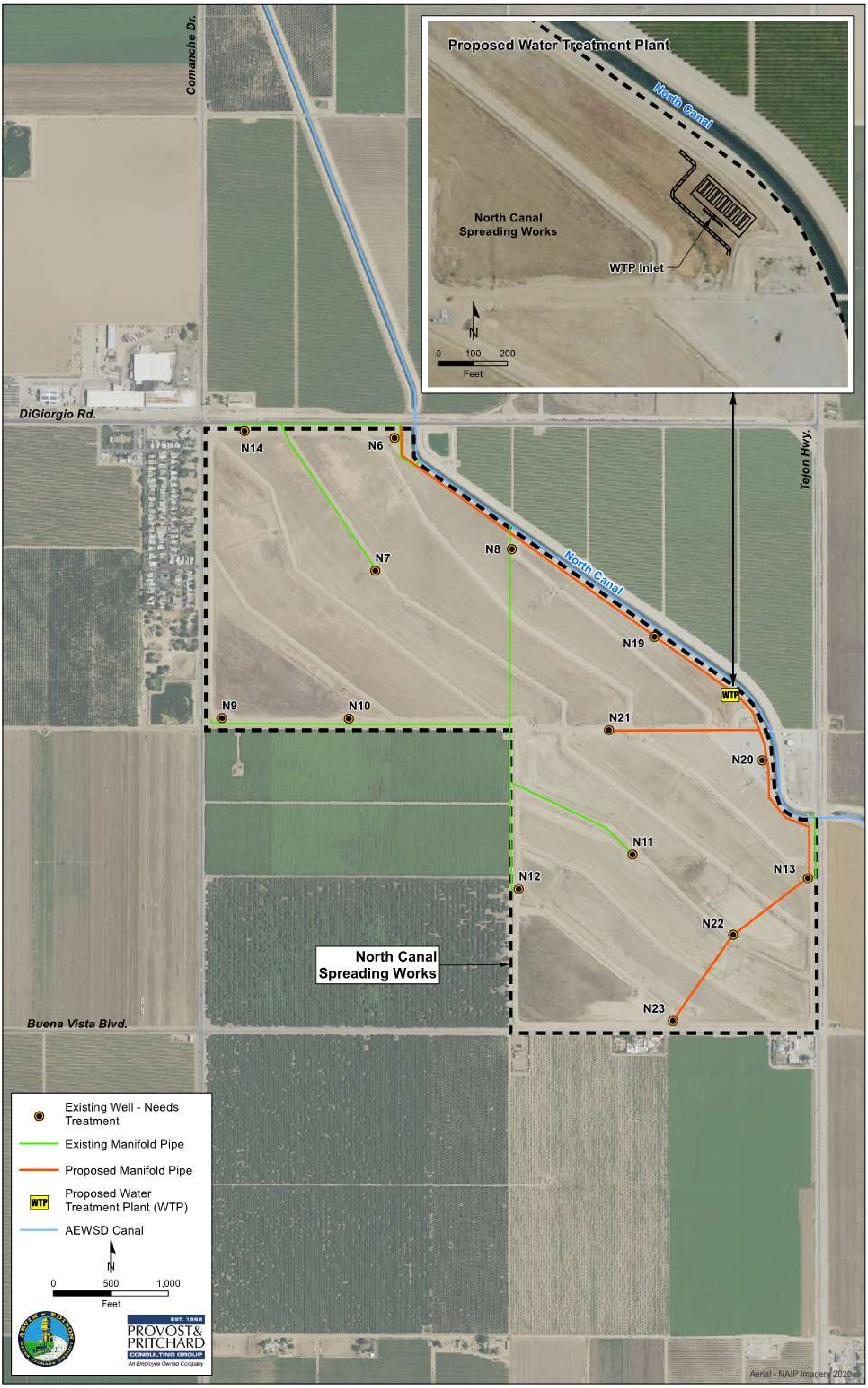


Figure 7-3: Alternative 2: North Canal Treatment Plant

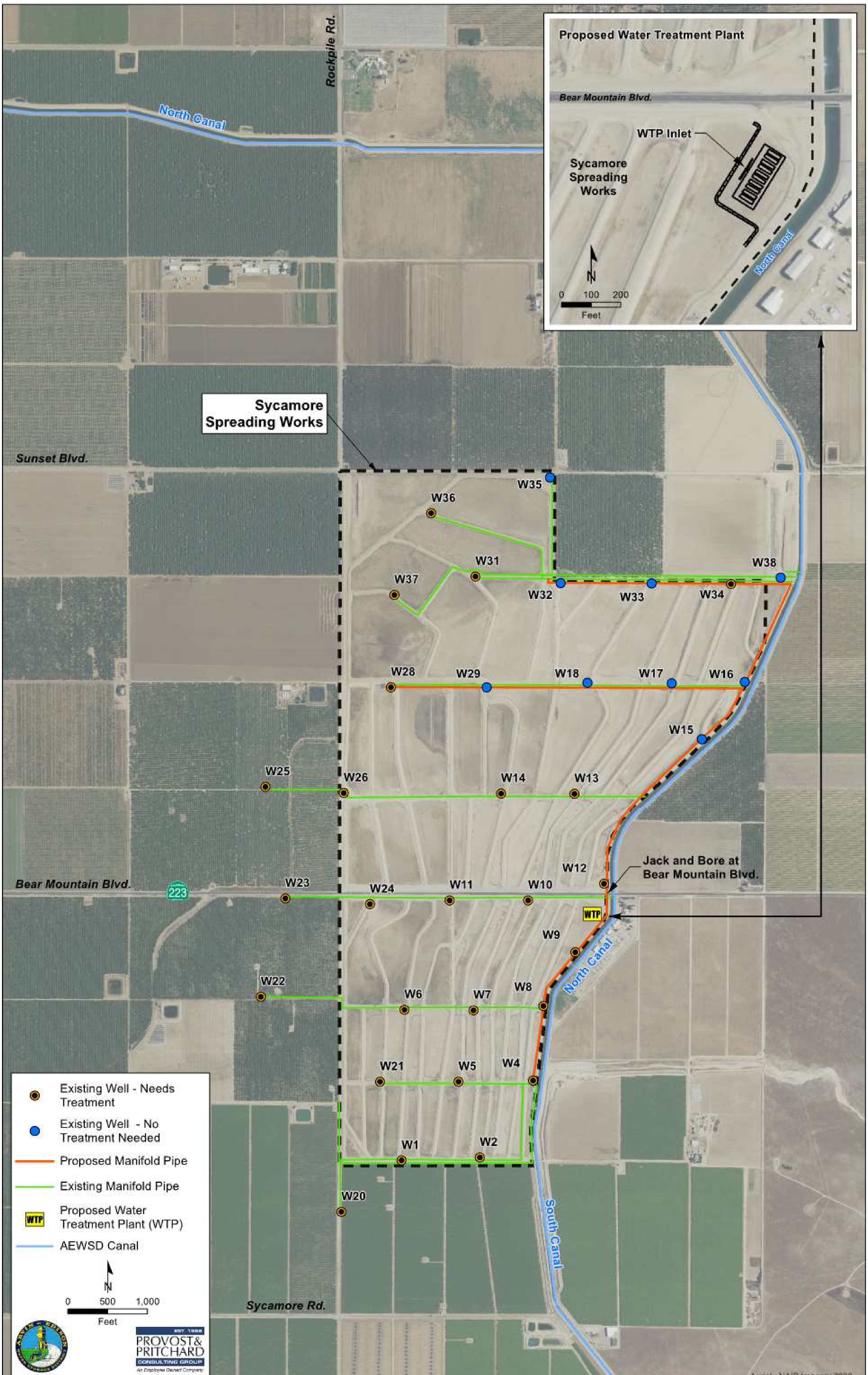


Figure 7-4: Alternative 2: Sycamore Treatment Plant

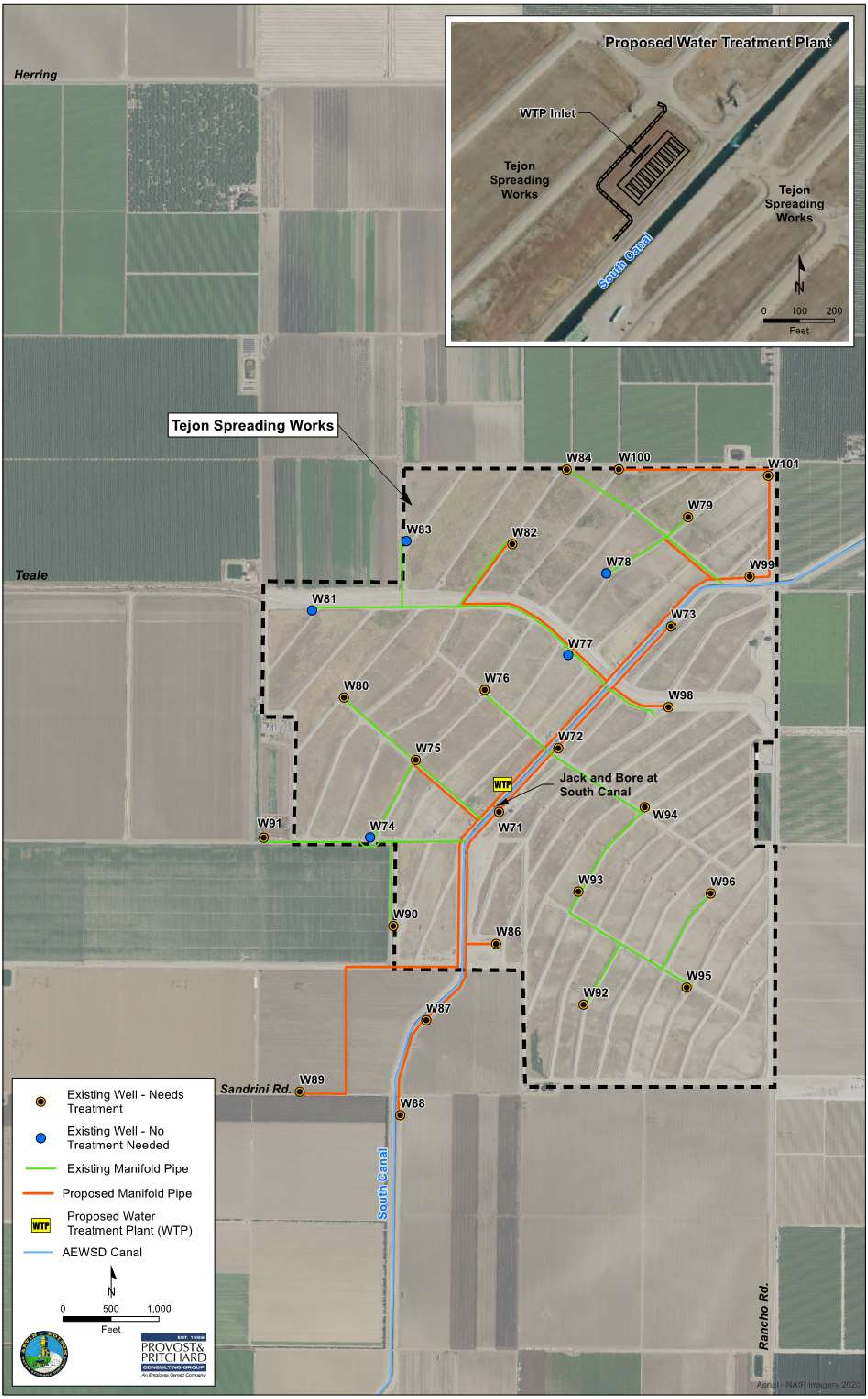


Figure 7-5: Alternative 2: Tejon Treatment Plant

7.4.2 Staged Parallel Operation

In order to improve process reliability and operability without operation of contactors in series, it is proposed that the treatment plant be operated with the contactor cells in a staged parallel mode. In staged parallel operation, each contactor cell is operating at a different point in its carbon replacement cycle. Some of the cells will contain relatively new carbon while other cells will be nearing the need for replacement. With enough cells, it will be permittable for one or more cells to have low-level TCP breakthrough into the effluent since the effluent from these cells will be blended with the remaining cells that are producing TCP-free water. It has been assumed that at least ten (10) contactor cells are required for this operational approach to be feasible.

7.4.3 Backwash Management

Similar to the wellhead treatment alternative, the carbon must be backwashed after delivery and may need to be backwashed after being placed into service to mitigate head loss build-up. However, due to the larger filter area, greater flow rates and water volumes will be required. A dedicated backwash water supply tank and pumps will be necessary to supply the backwash water. It has been assumed that backwash water can be discharged into a nearby spreading pond.

7.4.4 Carbon Replacement

Due to the inability to operate contactors in series, carbon usage rates for this alternative are anticipated to be higher than for the traditional pressure vessel wellhead treatment system alternative. The District would need to change out the carbon in the individual contactor cells prior to, or immediately after, TCP is detected in the effluent. At change-out, the carbon near the top of the bed would likely be fully exhausted, but there would still be significant TCP adsorption capacity remaining within the carbon lower in the bed. A carbon utilization factor of 0.8 (80% utilization) has been assumed to arrive at a carbon usage rate estimate of 0.16 lbs/1,000 gallons (52.1 lbs/acre foot)

7.4.5 Carbon Handling

Due to the larger volumes of carbon involved and the relative inaccessibility of the filter cells, carbon handling for a large gravity system would be more complicated than for a wellhead treatment system. A permanent eductor slurry transport system; contactor wall wash-down nozzles; and delivery loading stations will need to be incorporated into the treatment plants.

7.4.6 Impact of Treatment on Well Capacity

The water produced by the wells will need to be pumped from the well locations to the centralized treatment facility. It will also need to be lifted approximately 25 feet to the filter inlet. The impact to the well pumping capacities is anticipated to be similar to that of the wellhead treatment alternative. An additional 7 wells with wellhead treatment will need to be constructed to make up for the reduced well capacities.

7.5 Alternative 3: Centralized Treatment at the Intertie Pipeline

During dry years, when water is being recovered from the groundwater bank for delivery to MWD, there is typically an equal or greater volume of water being recovered from the bank for delivery to the District's growers. There is currently no requirement for the water delivered to the District's growers to be treated for removal of TCP. Yet, because the recovered grower water intermingles with the MWD water in the North and South Canals, implementation of treatment alternatives 1 or 2 would require that all of the water pumped from the recovery wells be treated whenever deliveries to MWD are occurring. The wellhead and semi-centralized treatment approaches described above would therefore result in the need to construct treatment plants with a combined capacity in excess of the 175 cfs maximum MWD program delivery rate. The Alternative 1 and 2 treatment plants would also treat approximately twice the volume of water that will ultimately end up in the California Aqueduct.

The only practical way to treat the water delivered to MWD without treating the water delivered to the District's growers is to treat the water at the Intertie Pipeline. This approach would involve construction of a treatment plant at the entrance to the Intertie Pipeline, along the alignment of the Intertie Pipeline, or at the California Aqueduct turnout. For purposes of this analysis, it has been assumed that such a treatment plant would be constructed at the head of the Intertie Pipeline near the existing Intertie Pump Station. This location should prove the easiest to acquire the necessary additional property and the District already has infrastructure in the area.

However, a very significant feasibility concern applicable to this treatment alternative is that groundwater treatment is no longer being considered – the water reaching the Intertie Pipeline has intermingled with imported surface water as well as with turbidity, debris, algae, aquatic pesticides, etc. introduced in the open canal system and the treatment plant would therefore more appropriately be considered a surface water treatment plant. As described in this report section, there are significant technological challenges associated with utilizing an adsorption treatment process to remove trace organic contaminants such as TCP from surface water.

Advantages	Disadvantages
• Lowest required treatment plant capacity • Lowest volume of water treated • No loss of spreading basin area • No impact on recovery well pump capacity • Only one treatment facility to manage	• Greatest level of design, performance, and cost uncertainty • Need to treat intermingled high-TOC and TSS surface water • Need to treat the water from wells with TCP levels below the MCL • Large solids including grape leaves and tumble weeds will need to be screened out prior to treatment • Solids will inevitably be filtered out by GAC beds • Aquatic pest control treatments in spreading basins and canals may interfere with GAC treatment • Need for acquisition of property near the intertie pumping station • Requires re-pumping of water at the Intertie Pipeline • The treatment plant is significantly more operationally complex than the other two alternatives

7.5.1 GAC Design Parameters and System Description

The design parameters applicable to a GAC treatment plant at the Intertie Pipeline would differ significantly from the gravity contactor treatment plants proposed in Alternative 2. The most significant difference is that, as water is conveyed from the recovery wells to the Intertie Pipeline through the North and South canals, it intermingles with any imported surface water being delivered to the District at the same time. That surface water contains much higher levels of suspended solids and background total organic carbon compared to the water pumped from the recovery wells. Algae and weeds growing in the canals and wind-blown leaves, tumbleweeds, and dust will also negatively affect the water quality as it relates to TCP treatment (refer to Figures 7-6 and 7-7). Some, or most, of the suspended solids will unavoidably be captured by the GAC system, requiring that the system be designed as a filter adsorber vs. the non-filtering contactors proposed for Alternative 2.

While filter adsorbers are in common use at drinking water surface water treatment plants, those treatment plants are not designed for the type of trace organic contaminant removal required for this application and most plants incorporate a chemical coagulation and clarification process such as sedimentation basins upstream from the filter adsorbers to remove most of the raw water turbidity, algae, and a portion of the background TOC prior to filtration. Simpler direct filtration plants, which involve no pre-treatment other than in-line coagulant addition, are also in use but are limited to raw waters that are very low in turbidity and do not pose other water quality challenges. In the District's case, it would be ideal if the water could pass through the GAC beds without any pretreatment and without any turbidity/solids removal. Unfortunately, that scenario is not feasible.

Allowing high turbidity water that has not been chemically pretreated or clarified to pass through a filter bed is not a concept that is normally contemplated for drinking water treatment applications where turbidity removal is a primary treatment objective and Provost & Pritchard is unaware of it having ever been deliberately attempted. There is therefore no operational experience to aid in establishing design parameters.

If a coagulant is not added to the water, it is likely, at least initially, that relatively long filter run lengths would result due to the poor capture of the turbidity particles within the GAC bed. However, even under the most optimistic assumptions, relatively frequent maintenance backwashing will still be required. The backwash frequency will vary depending on the suspended solids content of the incoming water from the South Canal. A preliminary estimate of the backwash frequency would be on the order of every couple of days to a week. However, it is reasonably likely that, if no coagulant or filter aid is used, backwashing of the filters would not be effective at restoring them back to their clean bed head loss. A certain percentage of the heavier solids would likely sink deep into the bed where they would accumulate until the next media change-out. Surface wash and/or air scour systems would almost certainly need to be incorporated into the design to enhance backwash effectiveness. Ultimately, it may be impossible to manage head loss at such a treatment plant without coagulant addition.

The addition of a coagulant to the water would result in solids being captured in the upper portion of the GAC bed where they would be more easily removed through backwashing. Adding a coagulant would also greatly increase the design and operational complexity of the treatment plant. Not only would a primary coagulant chemical feed system and mixing need to be provided upstream of the GAC beds, but discharging backwash water containing aluminum or iron-based coagulant sludge into an unlined pond would likely not be permitted by the Regional Water Quality Control Board. Instead, an engineered backwash water thickening and solids dewatering process ("residuals management" process) with its own polymer chemical feed system would be required. It is not uncommon for water treatment plant residuals management systems to be more complicated, troublesome, and difficult to operate than the filtration system itself. The costs associated with these additional treatment plant features will offset a significant portion of the capital cost savings resulting from the reduction in treatment plant capacity compared to Alternative 2. The cost estimates contained in Section 8 include coagulant feed and residuals management systems.

This alternative would also require the use of larger mesh size and harder, more abrasion-resistant GAC products. The larger mesh size would result in lower head losses through the bed and longer filter runs but would be less effective at removing trace contaminants such as TCP from the water. The use of harder carbons would be necessary to prevent the media from wearing down due to inter-particle abrasion during backwashing. The combination of higher TOC levels in the canal water; the coarser media mesh size; and the frequent backwashing of the bed will result in significantly greater carbon usage rates and higher resulting unit operating costs per acre foot treated compared to Alternatives 1 and 2.

Similar to Alternative 2, the beds will need to incorporate an underdrain system capable of handling carbon fines, such as a wedge wire system. Gravity filter adsorbers typically operate at bed depths ranging from 4 – 6 feet. A 6-foot-deep bed has been assumed. Hydraulic loading rates for filter adsorbers typically range from 2 to 6 gpm/ft^2. A value of 3 gpm/ft^2 has been assumed given that no upstream clarifier is proposed. This combination of 6-foot bed depth and 3 gpm/ft^2 hydraulic loading rate results in an EBCT of 15 minutes.

Using the above parameters results in the following preliminary system sizing:

Parameter	Intertie Treatment Plant
Flow Rate (cfs)	175
Flow Rate (gpm)	78,545
EBCT (minutes)	15.0
HLR (gpm/ft²)	3.0
Number of Cells	20
Number of Cells (During backwash and change-out)	19
Filter Area -Total (ft2)	26,180
Filter Area - Per Cell (ft²)	1,310
GAC depth (ft)	6
Approx. Carbon Capacity – Total (lbs)	4,400,000
Approx. Carbon Capacity – Cell (lbs)	220,000
Backwash Rate (gpm/ft²)	14
Backwash Flow Rate (gpm)	18,340
Approximate Filter Dimensions (ft)	21 x 63
Approximate facility site footprint (acres)	3.5

The size of the filter adsorber structure would be approximately three times the filter area. However, additional space will be required for inlet and outlet pipelines, carbon delivery truck access, a control building, the chemical storage and feed systems, etc. The estimated height of the contactor structure is approximately 25 feet. The residuals management system, described in Section 7.5.4, is anticipated to occupy 15 acres of land by itself.

Similar to the other alternatives, the treatment plant will need to be designed to prevent dewatering of the GAC system. A seal well incorporating an overflow weir can be used for this purpose.

Figure 7-6: Build-up of Grape Leaves on Canal Screens

Figure 7-7: Tumble Weed Build-up in the Canal

7.5.2 Implementation Risk

The approach described in this section, operation of a filter adsorber for removal of a trace organic contaminant without any clarification pretreatment, is unconventional and Provost & Pritchard is unaware of any similar treatment plant in service. For this reason, there is significant uncertainty in the feasibility of the approach, the configuration of the treatment plant, the filter operating parameters, and in the resulting carbon usage rate. Although a pilot study could help refine estimates and assumptions regarding operating parameters and performance, there is a high likelihood that it will be determined that operation without the addition of a coagulant is infeasible. The cost estimates presented in Section 8 therefore assume coagulant addition and a lagoon-type solids handling system. Regardless of whether a coagulant is ultimately required or not, it is estimated that the cost of ongoing carbon replacement for this alternative will rapidly offset any potential capital costs savings over Alternative 2.

7.5.3 Staged Parallel Operation

Similar to the spreading basin contactor systems, it is proposed that the Intertie Pipeline system be operated in a staged parallel mode with carbon change-outs staggered. However, due to the need for regular backwashing, which will disrupt the adsorption mass transfer zone in the carbon beds, it is anticipated that effluent TCP levels at each filter cell will be more unpredictable than for Alternative 2.

7.5.4 Backwash Management and Solids Handling

Unlike the other two alternatives, backwashing of the Intertie filter adsorber system would need to occur frequently to keep head loss through the bed to acceptable levels. A dedicated backwash water supply tank and pumps will be necessary to supply the backwash water. As noted previously, the Central Valley Regional Water Quality Control Board is unlikely to allow discharge of coagulant-laden backwash water into an unlined pond. This alternative will therefore also require construction of a residuals management system. In its simplest and least expensive form, a residuals management system would consist of a polymer feed system, several large, concrete lined washwater recovery and solids drying lagoons, and a reclaim pumping station. More sophisticated and less space-intensive residuals management systems incorporating gravity thickeners and mechanical dewatering (centrifuges, presses, etc.) would be significantly more expensive to construct. The City of Fresno's 125 cfs Southeast Surface Water Treatment Facility (SESWTF) construction project, which was used as a basis for filter cost estimates in Section 8, included a similar residuals management approach and required approximately 10 acres of concrete lined lagoons. However; the proposed Intertie Pipeline treatment plant has a total filter adsorber area almost three times the SESWTF filter area and will therefore require more lagoon storage volume. A total of 15 acres of lagoons has been assumed.

7.5.5 Raw Water Pumping

Because this alternative places treatment after the water pumped by the recovery wells has entered the canal system, it will be necessary to include a new pump station to lift the water into the top of the treatment system. The existing Intertie Pumping Station would then pump the treated water into the Intertie Pipeline. It has been assumed that the new raw water pumping station would be almost identical in design to the existing Intertie Pumping Station except that the raw water pumping head would be approximately one-half the head produced by the Intertie Pumping Station.

7.5.6 Carbon Replacement

The carbon usage rate for this alternative is anticipated to be significantly higher than for the traditional pressure vessel wellhead treatment and spreading basin contactor alternatives. The three primary reasons to expect a higher carbon usage rate are the higher average TOC levels in the raw water; the frequent backwashing of the filter adsorbers, which will disrupt the adsorption mass transfer zone and abrade the carbon; and the need to use a coarser carbon mesh size, which is less effective at removing trace contaminants such as TCP. Similar to the spreading basin contactor alternative, the District would need to change out the carbon in the individual contactor cells prior to, or immediately after, TCP is detected in the effluent. At change-out, the carbon near the top of the bed would likely be fully exhausted, but there would still be significant TCP adsorption capacity remaining within the carbon lower in the bed.

The effect of higher TOC levels on carbon usage rates is difficult to predict. The chemical nature and molecular weights of the TOC compounds will vary over time based on the origin of the imported water, the season, and hydrologic conditions. Similarly, the effects of mesh size and the frequent backwashing of the GAC bed on the carbon usage rate are difficult to estimate. Considering all three factors together, carbon usage rates could easily be four times the typical wellhead treatment value. A value of 0.52 lbs/1,000 gallons has been assumed for the purpose of estimating operating costs and comparing alternatives, however, actual carbon usage rates may be higher.

7.5.7 Carbon Handling

Similar to the contactors proposed for the spreading works, a permanent eductor slurry transport system; contactor wall wash-down nozzles; and delivery truck loading stations will need to be incorporated into the design.

7.5.8 Impact on District's Aquatic Pest Control Program

The District adds copper, hydrogen peroxide, endothall, Roundup (glyphosate), and similar chemicals to the canals and spreading works for the control of aquatic weeds and algae. All of these compounds have the potential to adversely impact the GAC treatment process. In particular, the endothall and glyphosate will be adsorbed by the carbon, which will reduce its capacity for removal of TCP.

Further research into the concentrations of these compounds at the Intertie Pump Station would need to be conducted to better assess their potential impact on TCP treatment. Depending on the levels detected, the District might need to modify its aquatic pest control program to reduce impacts on the proposed TCP treatment process.

7.5.9 Impact of Treatment on Well Capacity

This alternative would have no impact on the capacity of the recovery wells. Construction of additional wells would not be required. However; a new raw water pumping station would be required.

7.5.10 South Canal Improvements

Significant modifications to the South Canal and Spillway Basin would be required to accommodate the proposed raw water pumping station and treatment plant while allowing for continued operation of the Intertie Pumping Station and South Canal. Proposed South Canal improvements are illustrated in Figure 7-8. Not shown are the approximately 15 acres of lined lagoons that would need to be constructed as part of the residuals management system.

Figure 7-8: Alternative 3 South Canal Improvements

8 Cost Analysis

8.1 Non-Treatment Costs Incurred by District

The MWD program was suspended in 2019 with 142,257 acre-feet of water stranded in the bank awaiting resolution of the TCP issue. Reference **Appendix I** for documents related to MWD's suspension of the program. Since July 2019:

- The District has not been able to deliver banked water to MWD;
- MWD has not been willing to deliver any additional water to the District for banking;
- The District has been unable to capture unrestricted water that would have previously been accepted using the WQSA program; and
- The District has not been able to wheel Kern Delta water being returned to MWD as part of the Kern Delta/MWD banking program.

Monetary impacts to the District directly associated with the above consequences of the TCP contamination have included the laboratory costs for TCP testing; the loss of MWD regulation fees associated with both delivery and return of water; the loss of Kern Delta wheeling fees; and the need to purchase water to replace lost WQSA and leave-behind water (from both District/MWD and Kern Delta/MWD banking programs). These impacts will continue until a project to mitigate the TCP contamination is constructed and operational, which is anticipated to be no sooner than the end of 2026. This date is based on the following schedule assumptions:

- Funding secured for project: 2022
- Property acquisition, design and permitting complete: End of 2024
- Construction complete: End of 2026

Specific monetary impacts to the District are described in more detail in the following sections.

8.1.1 Laboratory Costs

As of February 2021, the District had analyzed more than 400 samples for TCP. At a laboratory cost of $69/sample plus another $35/sample in lab staff labor to collect the samples, the total cost to the District up to February 2021 was $41,600. Assuming ongoing quarterly testing of each well, the District will continue to spend approximately $36,000 per year on TCP testing for the foreseeable future.

8.1.2 Lost Delivery and Returned Water Regulation Fees

Article 6 of the MWD Program agreement and a subsequent April 12, 2011 letter agreement specify regulation fees that MWD is required to pay the District whenever water is delivered to the District for regulation and whenever regulated water is returned to MWD (regulation fees). These regulation fees are in addition to fees paid by MWD for reimbursement of the actual costs of operating and administering the program. Similarly, when Kern Delta returns water to MWD as part of the Kern Delta/MWD banking program and that water is wheeled through the District's conveyance system to the California Aqueduct, Kern Delta pays the District delivery fees, which are in addition to fees paid by Kern Delta for reimbursement of operating costs. Suspension of the MWD program in 2019 due to TCP contamination has resulted in the loss of the regulation and wheeling fees that the District would otherwise have received during calendar years 2019 through 2026, when it is anticipated that a solution to the contamination will be in place. A detailed estimate of these fees is contained in **Appendix H** and summarized in Table 8-1.

Table 8-1: Value of Lost Fees

Year	Lost MWD Fees	Lost KD Wheeling Fees	Lost Fees (Total Cumulative)
2019	$667,000	$0	$667,000
2020	$249,136	$0	$916,136
2021	$3,681,313	$834,848	$5,432,297
2022	$2,357,198	$415,111	$8,204,606
2023	$3,775,375	$672,685	$12,652,666
2024	$5,632,837	$1,003,642	$19,289,145
2025	$7,139,534	$1,054,766	$27,483,444
2026	$969,478	$0	$28,452,922
		TOTAL	**$28,452,922**

The assumptions used in developing this estimate were:

- 50,000-acre feet of MWD Program water would have been delivered during calendar year 2019 and returned during 2021. The 50,000-acre foot assumption is a conservatively low estimate based on the 56,405-acre feet of water that was delivered by MWD to the Kern Delta Water Bank during 2019. Delivery and return during 2020 were assumed to be zero and 5,030-acre feet respectively. These assumptions are also consistent with actual Kern Delta Water Bank operations. The average of actual Arvin-Edison return volumes for model years 2014 and 2015 during the same months when Kern Delta returned water in 2020 (March – August) were used to arrive at the 5,030-acre foot estimate for Arvin-Edison return.
- In 2019 the District would have utilized the WQSA program to capture 30,000-acre feet of water beyond its Class 1 and Class 2 allocations. This is a representative value as experienced for similar prior hydrologic conditions.
- Beginning in 2022, District/MWD Program delivery, return, and WQSA volumes are based on actual volumes for model years 2007 onward. Projected year 2022 has been modeled to be the same as actual year 2007; projected year 2023 has been modeled to be the same as actual year 2008; etc. Actual year 2007 was chosen as the first model year because that was the year the WQSA and the Kern Delta MWD banking programs began and those programs have been in place since that time. The South Canal Improvement Project was also substantially complete. That project increased South Canal capacity therefore increasing the potential return capacity to MWD through the Intertie Pipeline.
- The volume of Kern Delta/MWD program water wheeled through the District's system is assumed to be 62% of the volume of the District/MWD Program returned water for the same period. The 62% assumption is based on the actual ratio of Kern Delta water wheeled through the District's system when compared to the District/MWD Program returned water during the 2014 and 2015 water years, which are the most representative years for projecting future activity based on current CVP and SWP operations and policies.
- The MWD Program agreement and April 12, 2011 letter agreement stipulate the delivery and return regulation fee amounts and the adjustment of those fee amounts each calendar year based on the Consumer Price Index, All Urban Consumers, All Items Index, Western Cities with Populations of 50,000 to 330,000 (CPI). Similar to how delivery, return, and WQSA volumes have been modeled based on actual values for past model years, the CPI adjustment for future years, beginning in 2022, was estimated using the CPI adjustment for past model years, starting with model year 2007.
- The District's Intake Canal is involved in conveying MWD water for delivery to Kern Delta for initial banking purposes, whereas a smaller portion of the Intake Canal and all of the North and South Canals are involved in conveying Kern Delta/MWD Program water to the Aqueduct. For allocating the wheeling fees, use of the Intake Canal to deliver MWD water to Kern Delta is considered "mid-system"

use and is allocated 30% of the wheeling fees for initial banking purposes. Use of the remaining portion of the Intake Canal and the North and South Canals to return water to the Aqueduct is allocated the remaining 70% of the wheeling fees. For the purpose of estimating lost District revenue associated with the Kern Delta/MWD Program, it has been assumed that MWD will continue to use the District's Intake Canal to deliver initial banking water to Kern Delta and therefore the District will continue to receive 30% of the wheeling fees and that only the equivalent 70% of those fees associated with return of Kern Delta/MWD water to the Aqueduct (corrected for point of delivery to the head end of the AE system) will be eliminated due to the District's inability to deliver water to the California Aqueduct due to TCP in the canal system.

- When the MWD Program was suspended, MWD had a WQSA credit of 65,781-acre feet. That credit can be used by MWD to offset regulation fees. The 65,781-acre foot credit, and additional credits for assumed future WQSA volumes, were used to offset future regulation fees.
- Delivery and return volumes were tracked on a calendar year basis to match MWD's supply accounting. The WQSA volumes were tracked on a water year basis (March 1 – February) to match the District's supply accounting.

8.1.3 Value of Lost WQSA and Leave-Behind Water

The volume of water that the District regulates with MWD using the WQSA program provisions amounts to an additional water supply for use by the District, which would otherwise be lost. This WQSA regulation can be viewed as an offset of an equal volume of water that the District would otherwise need to purchase from others. The suspension of the WQSA portion of the MWD Program has resulted in an estimated 30,000-acre feet of lost water in 2019 and is projected to result in additional lost water in near future years before the TCP contamination can be mitigated. As described in Section 8.1.2, future WQSA volumes have been estimated based on actual WQSA volumes during past model years. Furthermore, both District/MWD Program deliveries and Kern Delta wheeling results in a leave-behind of water contractually equal to 10% of the volume regulated/delivered. The assumed leave-behind percentages for the District/MWD Program have been conservatively reduced to 7% to account for likely "real" losses of water resulting from meter errors, evaporation, etc. The leave-behind associated with wheeling of water for the Kern Delta/MWD program is 3% for delivery of MWD water to Kern Delta mid-system and 7.8% for return of banked Kern Delta Program water to MWD. The 7.8% leave behind factor, calculated as (0.97/0.90)-1.0, accounts for the mid-system point of delivery and that a 3% loss was already applied for the initial delivery. As noted in Section 8.1.2, the cost analysis assumes that only water being returned to MWD as part of the Kern Delta/MWD Program is impacted by the TCP contamination. The 7.8% leave behind has not been discounted as was done for the WQSA water because this water is likely to be wheeled during periods when the District is already delivering water to its growers or MWD and real losses have already been accounted for as part of the accounting for those activities. Similar to the WQSA program, the leave behind water that the District has lost from both banking programs, and will lose in near-future years, is water that the District will now need to purchase to replace such supplies.

A conservatively low estimate of the cost of purchasing replacement water of $250 per acre foot has been assumed for 2019. This cost was escalated for future years using projected CPI values. The $250/AF value of water is well supported by several references including:

- Preliminary Financial Impact Analysis of Transitional Groundwater Pumping-Induced Subsidence on the Friant-Kern Canal as Proposed in the Tule Subbasin Groundwater Sustainability Plans (Stantec 2020)
- Nasdaq-Veles California Water Index (NQH2O)

A detailed estimate of the cost of lost WQSA and leave-behind water is contained in **Appendix H** and summarized in Table 8-2.

Table 8-2: Value of Lost Water

Water Year	WQSA (acre-feet)	MWD Leave Behind (acre-feet)	KD Leave Behind (acre-feet)	*Total Lost Water (acre feet)*	Cost of Water ($/AF)	Total Cost of Lost Water
2019	30,000	3,500	0	*33,500*	$250	$8,375,000
2020	0	0	0	*0*	$257	$0
2021	0	0	2,416	*2,416*	$261	$629,768
2022	0	132	1,170	*1,302*	$268	$348,367
2023	0	0	1,817	*1,817*	$279	$507,440
2024	0	0	2,727	*2,727*	$278	$757,098
2025	32,367	5,499	2,793	*40,658*	$285	$11,583,068
2026	31,446	4,331	0	*35,777*	$287	$10,284,362
					TOTAL	**$32,485,104**

8.2 Treatment Alternative 1: Wellhead Treatment

The estimated 50-year present worth cost of Alternative 1 is as follows:

Table 8-3: Treatment Alternative 1 Estimated 50-Year Cost

Cost	Estimate
Capital Cost	$173,800,000
50-Year O&M Cost	$344,400,000
TOTAL	**$518,200,000**

8.2.1 Capital Costs

Capital costs associated with Alternative 1: Wellhead Treatment include:

1. Design, construction, and permitting of forty-four (40) wellhead treatment plants and appurtenances to treat sixty-eight (68) of the District's existing eighty-six (86) wells.
2. Design, construction, and permitting of five (5) wellhead treatment plants and appurtenances to treat the Grower In-Lieu wells. Includes purchase of grower land needed to site the treatment plants.
3. Design, construction and equipping of seven (7) new wells and associated treatment plants to make up for lost recovery well capacity that would result from treating the 68 existing District-owned wells.
4. Design, construction, and permitting of additional manifold piping necessary to bypass water from wells with TCP levels below ½ of the MCL around the proposed wellhead treatment plants.
5. Property acquisition for expansion of the spreading works to compensate for the spreading area that will be lost due to construction of the treatment plants. A property value of $30,000 per acre has been assumed.

Capital cost estimates for these items are summarized below. More detailed estimates for the treatment items can be found in **Appendix E**. A detailed breakdown of the new well costs is contained in **Appendix D**. The capital cost estimates for the wellhead treatment plants are based on extensive, recent bid results for similar treatment plants constructed for municipal water agencies. Well construction capital cost estimates are based on costs for recent District recovery well construction and equipping projects. The cost for construction of manifold piping and replacement of lost spreading pond area is an independent estimate.

Table 8-4: Treatment Alternative 1 Estimated Capital Costs

Parameter	Capital Cost Estimate
Forty (40) treatment plants for 68 of the 86 existing District wells	$136,500,000
Five (5) treatment plants for grower in lieu wells	$9,900,000
Seven (7) new wells	$7,400,000
Treatment of seven new wells	$16,800,000
Additional manifold piping	$2,900,000
Replacement of lost spreading works	$300,000
TOTAL	**$173,800,000**

8.2.2 O&M Costs

Operations and maintenance (O&M) costs that would be incurred by the District after construction of the project improvements include:

1. Periodic replacement of the carbon. A carbon usage rate of 0.13 lbs./1,000 gallons (42.4 lbs./AF) has been assumed for this alternative.
2. Additional pumping power to overcome the approximately 10 psi of head loss assuming a 70% pump efficiency.
3. Labor as follows:
    a. One full-time staff position has been assumed to manage the program
    b. Additional staff time of approximately ½ hour per week per treatment plant
    c. 30 minutes per sample collected
    d. 8 hours per carbon change-out, and
    e. $54.41 per hour fully burdened labor rate
4. Laboratory charges for monitoring TCP levels as follows:
    a. Each well will be sampled quarterly
    b. Each vessel pair will be sampled monthly
    c. The water entering the Intertie Pipeline will be sampled monthly
    d. It has been assumed that sampling will only occur when the Intertie Pipeline is active, which is approximately 47% of the time.
    e. The per-sample cost has been assumed to be $69
5. Maintenance and repairs of the treatment systems. An annual value equal to 2.5% of the assumed vessel cost has been included.

These O&M costs are summarized below. More detailed estimates can be found in **Appendix E**.

Table 8-5: Treatment Alternative 1 Estimated O&M Costs

O&M Cost Item	Annual Cost
Carbon	$3,861,000
Power	$198,800
Labor	$259,000
Laboratory	$95,000
Maintenance	$1,959,400
TOTAL	**$6,373,200**

8.3 Treatment Alternative 2: Spreading Works

The estimated 50-year present worth cost of Alternative 2 is as follows:

Table 8-6: Treatment Alternative 2 Estimated 50-Year Cost

Cost	Estimate
Capital Cost	$125,800,000
50-Year O&M Cost	$339,500,000
TOTAL	**$465,300,000**

8.3.1 Capital Costs

Estimated capital costs associated with Alternative 2: Centralized Treatment at the Spreading Works include:

1. Design, construction, and permitting of three centralized gravity GAC contactor treatment plants to treat sixty-three (63) wells.
2. Design and construction of manifold pipelines to connect the wells at each spreading facility to their associated centralized treatment plant and to bypass the water produced by wells with TCP concentrations below ½ of the MCL around the treatment plants. This cost item includes a jack and bore crossing of Highway 223 at the Sycamore Spreading Works and a jack and bore crossing of the Arvin-Edison canal at the Tejon Spreading Works.
3. Design and construction of five (5) stand-alone wellhead treatment plants and appurtenances for North Canal wells N1 through N5.
4. Design, construction, and permitting of five (5) wellhead treatment plants and appurtenances to treat the Grower In-Lieu wells. Includes purchase of grower land needed to site the treatment plants.
5. Design, construction and equipping of seven (7) new wells and associated treatment plants to make up for lost recovery well capacity that would result from treating the 68 existing wells.
6. Property acquisition for expansion of the spreading works to compensate for the spreading area that will be lost due to construction of the treatment plants. A property value of $30,000 per acre has been assumed.

Capital cost estimates for these items are summarized below. More detailed estimates can be found in **Appendix F**.

Table 8-7: Treatment Alternative 2 Estimated Capital Costs

Parameter	Capital Cost Estimate
Three (3) gravity GAC contactor treatment plants with manifold piping	$66,900,000
Manifold piping	$12,700,000
Five (5) wellhead treatment plants for north wells	$12,000,000
Five (5) treatment plants for grower in lieu wells	$9,900,000
Seven (7) new wells	$7,400,000
Treatment of 7 new wells	$16,800,000
Replacement of lost spreading pond area	$140,000
TOTAL	**$125,840,000**

The capital cost estimates for the wellhead treatment plants are based on extensive, recent bid results for similar treatment plants constructed for municipal water agencies. Manifold pipe lengths and diameters were tabulated taking into account manifold piping that is already in place and assuming a maximum velocity of 5 feet per second. The cost of the resulting piping was independently estimated. Well construction capital cost estimates are based on recent District recovery well construction and equipping projects. The cost for replacement of lost spreading pond area was independently estimated.

The capital cost estimates for the gravity GAC contactor structure and backwash pumping facilities were developed as follows.

1. Actual 2015 bid costs for the 7,200 square foot, 8-cell filtration system at the City of Fresno's Southeast Surface Water Treatment Facility (SESWTF) were obtained.
2. Cost-capacity curves presented in the Cost Estimating Manual for Water Treatment Facilities (McGivney & Kawamura, 2007) were used to scale the SESWTF costs based on the total filter area. Two separate cost-capacity curves were used: one for the gravity filter structure with inlet channel, underdrain system, and effluent piping; and one for the filter backwash pumping system
3. The 2007 McGivney & Kawamura cost curves were escalated by a factor of 1.66 to calibrate them to the actual 2015 SESWTF costs.
4. The cost curves were increased by another factor of 1.22 based on the RS Means historical cost index escalation from 2015 to 2021.
5. A third factor of 1.25 was applied to account for the increase in filter bed depth and filter cell count compared to the SESWTF project.

Additional required treatment plant features that were not accounted for in the methodology described above included the initial load of GAC media; wash water storage tank; control and maintenance building at each treatment plant; carbon delivery station and eductor slurry transfer system; and site civil improvements including fencing, drainage, and surfacing. GAC media costs were estimated to be \$1.50/lb. Note that this is lower than the assumed carbon change-out costs contained in the O&M cost estimates because disposal of spent media is not required. The cost of the wash water storage tank was estimated assuming the use of a bolted steel tank sized for a 30-minute backwash of a single contactor cell.

Mobilization and electrical and controls costs were estimated at 5% and 10% of the direct cost subtotal respectively. A contingency of 20% was applied to the direct cost estimate. Design; construction management and inspection; and environmental, legal, and administrative costs were estimated at 5%, 2.5%, and 1.5% of the estimated construction cost respectively.

8.3.2 O&M Costs

Operations and maintenance (O&M) costs that would be incurred by the District after construction of the project improvements include:

1. Periodic replacement of the carbon. A carbon usage rate of 0.13 lbs./1,000 gallons (42.4 lbs./AF) has been assumed for the pressure vessel wellhead treatment plants. A higher carbon usage rate of 0.16 lbs./1,000 gallons (52.1 lbs./AF) has been assumed for the gravity contactors.
2. Additional pumping power to overcome the approximately 10 psi of head loss assuming a 70% pump efficiency.
3. Labor as follows:
    a. One full-time staff position has been assumed to manage the program
    b. Additional staff time of approximately ½ hour per week per wellhead treatment plant and 5 hours per week per gravity plant
    c. 30 minutes per sample collected
    d. 24 hours per carbon change-out
    e. \$52.41 per hour fully burdened labor rate
4. Laboratory charges for monitoring TCP levels as follows:
    a. Each well will be sampled quarterly
    b. Each vessel pair and gravity contactor cell will be sampled monthly

   c. The water entering the Intertie Pipeline will be sampled monthly
   d. It has been assumed that sampling will only occur when the Intertie Pipeline is active, which is approximately 47% of the time.
   e. The per-sample cost has been assumed to be $69
5. Maintenance and repairs of the treatment systems. An annual value equal to 2.5% of the assumed vessel cost and 1.5% of the gravity contactor construction cost has been included.

These O&M costs are summarized below. More detailed estimates can be found in **Appendix F**.

Table 8-8: Treatment Alternative 2 Estimated O&M Costs

O&M Cost Item	Annual Cost Estimate
Carbon	$4,613,000
Power	$198,800
Labor	$211,000
Laboratory	$44,000
Maintenance	$1,216,900
TOTAL	**$6,283,700**

8.4 Treatment Alternative 3: Intertie Pipeline

The estimated 50-year present worth cost of Alternative 3 is as follows:

Table 8-9: Treatment Alternative 3 Estimated 50-Year Cost

Cost	Estimate
Capital Cost	$115,100,000
50-Year O&M Cost	$492,700,000
TOTAL	**$607,800,000**

8.4.1 Capital Costs

Estimated capital costs associated with Alternative 3: Centralized Treatment at the Intertie Pipeline include:
1. Design, construction, and permitting of a raw water lift pump station to pump water from the South Canal to the treatment plant; canal improvements; and modifications to the spillway basin.
2. Design, construction, and permitting of a single 175 cfs centralized filter adsorber treatment plant at the head of the Intertie Pipeline. Treatment plant costs include a coagulant feed system and 15 acres of lined washwater and solids drying lagoons.
3. Property acquisition. A property value of $30,000 per acre has been assumed.

Capital cost estimates for these items are summarized below. More detailed estimates can be found in **Appendix G**.

Table 8-10: Treatment Alternative 3 Estimated Capital Costs

Parameter	Capital Cost Estimate
Pump station, canal improv., property acquisition	$14,400,000
Centralized filter adsorber treatment plant w/ residuals management system	$100,700,000
TOTAL	**$115,100,000**

The capital cost estimates for the gravity GAC filter/adsorber structure, backwash pump station, surface wash system, and air scour system were developed as follows.

1. Actual 2015 bid costs for the 7,200 square foot, 8-cell filtration system at the City of Fresno's Southeast Surface Water Treatment Facility (SESWTF) were obtained.
2. Cost-capacity curves presented in the Cost Estimating Manual for Water Treatment Facilities (McGivney & Kawamura, 2007) were used to scale the SESWTF costs based on the total filter area. Four separate cost-capacity curves were used: one for the gravity filter structure with inlet channel, underdrain system, and effluent piping; one for the filter backwash pumping system; one for the surface wash system; and one for the air scour system.
3. The 2007 McGivney & Kawamura cost curves were escalated by a factor of 1.66 to calibrate them to the actual 2015 SESWTF costs.
4. The cost curves were increased by another factor of 1.22 based on the RS Means historical cost index escalation from 2015 to 2021.
5. A third factor of 1.25 was applied to the gravity structure only to account for the increase in filter bed depth and filter cell count compared to the SESWTF project.

The capital cost estimate for the residuals management system was developed as follows:

1. Actual 2015 bid cost for the lined lagoon residuals management system at the City of Fresno's SESWTF was obtained.
2. The cost of the SESWTF lagoon system was increased by 50% to account for the approximately 3-times larger filter area associated with the proposed treatment plant.
3. The 2015 bid cost was increased by a factor of 1.22 based on the RS Means historical cost index escalation from 2015 to 2021.

Additional required treatment plant features that were not accounted for in the methodology described above and were independently estimated included the initial load of GAC media; wash water storage tank; control and maintenance building; carbon delivery station and eductor slurry transfer system; coagulant and polymer feed systems; site civil improvements including fencing, drainage, and surfacing; mobilization; electrical and controls; and project soft costs.

- GAC media costs were estimated to be $1.50/lb. Note that this is lower than the assumed carbon change-out costs contained in the O&M cost estimates because disposal of spent media is not required.
- The cost of the wash water storage tank was estimated assuming the use of a bolted steel tank sized for a 30-minute backwash of a single filter cell.
- Mobilization and electrical and controls costs were estimated at 5% and 10% of the direct cost subtotal respectively.
- A contingency of 20% was applied to the direct cost estimate.
- Design; construction management and inspection; and environmental, legal, and administrative costs were estimated at 5%, 2.5%, and 1.5% of the estimated construction cost respectively.

8.4.2 O&M Costs

Operations and maintenance (O&M) costs that would be incurred by the District after construction of the project improvements include:

1. Periodic replacement of the carbon. A carbon usage rate of 0.52 lbs./1,000 gallons (169.4 lbs/acre foot) has been assumed.
2. Pumping power to lift the water approximately 23 feet assuming an 70% pump efficiency.
3. Labor as follows:
    a. One full-time staff position has been assumed to manage the program and operate the treatment plant
    b. 30 minutes per sample collected
    c. 24 hours of additional labor per carbon change-out
    d. $52.41 per hour fully burdened labor rate
4. Laboratory charges for monitoring TCP levels as follows:
    a. Each well will be sampled quarterly
    b. Each filter cell will be sampled weekly
    c. The water entering the Intertie Pipeline will be sampled monthly
    d. It has been assumed that sampling will only occur when the Intertie Pipeline is active, which is approximately 47% of the time.
    e. The per-sample cost has been assumed to be $69
5. Maintenance and repairs of the treatment systems. An annual value equal to 1.5% of the plant construction cost has been included.
6. The cost of coagulant chemical (assumed to be liquid aluminum sulfate at a dosage of 10 mg/L).

These O&M costs are summarized below. More detailed estimates can be found in **Appendix G**.

Table 8-11: Treatment Alternative 3 Estimated O&M Costs

O&M Cost Item	Annual Cost Estimate
Carbon	$7,633,000
Power	$112,100
Labor	$149,000
Laboratory	$44,000
Maintenance	$1,079,900
Coagulant	$100,800
TOTAL	**$9,118,800**

9 Project Recommendation

The estimated capital and O&M costs for each of the treatment alternatives are summarized below:

Table 9-1: Present Worth Cost Summary

	Cost (Million $)		
	Alternative 1 (Wellhead)	**Alternative 2 (Spreading Works)**	**Alternative 3 (Intertie Pipeline)**
Capital	$173.8	$125.8	$115.1
O&M (10 Years)	$67.8	$66.8	$97.0
O&M (20 Years)	$134.4	$132.5	$192.3
O&M (30 Years)	$200.4	$197.6	$286.7
O&M (40 Years)	$271.3	$267.5	$388.2
O&M (50 Years)	$344.4	$339.5	$492.7
Total (10 Years)	$241.6	$192.6	$212.1
Total (20 Years)	$308.2	$258.3	$307.4
Total (30 Years)	$374.2	$323.4	$401.8
Total (40 Years)	$445.1	$393.3	$503.3
Total (50 Years)	$518.2	$465.3	$607.8

The only way to fully mitigate the TCP contamination and restore the MWD Program's benefits is to treat a large portion of the water pumped from the contaminated recovery wells. The apparent lowest capital cost treatment approach is to construct a 175 cfs filter adsorber treatment plant at the Intertie Pipeline (Treatment Alternative 3). However, the estimated annual O&M costs for that alternative, and in particular the carbon usage rate, are expected to be significantly higher and have a much greater level of uncertainty than the other two alternatives. Factors that affect the carbon usage rate for Alternative 3 that are not well defined include:

1. How frequently surface water will intermingle with the recovered groundwater in the canal and at what ratio;
2. Which surface water source(s) will be present in the canal;
3. What the TOC concentration and molecular weight characteristics are for the surface water source(s) (these TOC characteristics will vary seasonally);
4. What carbon mesh size will be required to maintain acceptable head loss rise; and
5. How frequently the filter adsorbers will need to be backwashed.

Given the anticipated high O&M costs and significant uncertainty associated with Alternative 3, it is recommended that the District implement Alternative 2: gravity GAC contactors at each of the spreading works. The lower O&M costs associated with Alternative 2 are predicted to offset the higher capital cost in less than 10 years. Alternative 2 would also provide the District with the flexibility of treating the water delivered to the District's growers should that be required in the future.

Appendix A TCP Results

NORTH CANAL WELLS - 23

Year	2018						2019		2020								2021							
		COMPARE		COMPARE																				
Well	Q1 (FGL)	Q2 (FGL)	Q2 (BC)	Q2 (APPL)	Q2 (FGL)	Q2 (BC)	Q1 (APPL)	Strength of Q1	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4
N1	0.055	0.069					0.039	x 8	0.050	x 10	0.053	x 11	0.045	x 9	0.054	x 11	0.036	x 7	0.043	x 9				
N2	0.020	0.132					0.084	x 17	0.067	x 13	0.099	x 20	0.050	x 10			0.048	x 10	0.081	x 16				
N3	0.032	0.203					0.089	x 18	0.104	x 21	0.153	x 31	0.118	x 24			0.151	x 30		x				
N4	0.028	0.050							0.031	x 6	0.080	x 16	0.082	x 16	0.078	x 16	0.057	x 11	0.068	x 14				
N5	0.326	0.220					0.150	x 30	0.161	x 32	0.195	x 39	0.136	x 27			0.156	x 31	0.185	x 37				
N6	0.530	0.323		0.170	0.256	0.160			0.211	x 42	0.266	x 53	0.197	x 39			0.223	x 45		x				
N7	0.233	0.215							0.141	x 28	0.138	x 28	0.126	x 25	0.130	x 26	0.114	x 23	0.160	x 32				
N8	0.292	0.341							0.140	x 28	0.081	x 16	0.172	x 34			0.135	x 27	0.160	x 32				
N9	0.086	0.270							0.145	x 29	0.248	x 50	0.215	x 43			0.200	x 40		x				
N10	0.098	0.282		0.170	0.254	0.160			0.182	x 36	0.192	x 38	0.288	x 58			0.174	x 35	0.211	x 42				
N11	0.244	0.185							0.078	x 16	0.077	x 15	0.096	x 19			0.092	x 18	0.116	x 23				
N12	0.105	0.098							0.073	x 15	0.066	x 13	0.114	x 23			0.078	x 16	0.087	x 17				
N13	0.300	0.258	0.110						0.095	x 19	0.132	x 26	0.136	x 27			0.133	x 27	0.154	x 31				
N14	0.181	0.292							0.177	x 35	0.157	x 31	0.170	x 34	0.158	x 32	0.168	x 34	0.186	x 37				
N15																	ND	x		x				
N16																								
N17																	ND	x		x				
N18																	ND	x		x				
N19	0.116	0.197					0.096	x 19	0.079	x 16	0.135	x 27	0.114	x 23	0.140	x 28	0.104	x 21	0.136	x 27				
N20	0.120	0.039					0.028	x 6	0.034	x 7	0.025	x 5	0.047	x 9			0.042	x 8	0.061	x 12				
N21							0.110	x 22	0.056	x 11	0.033	x 7	0.079	x 16	0.075	x 15	0.053	x 11	0.097	x 19				
N22											0.032	x 6	0.057	x 11	0.065	x 13	0.055	x 11	0.072	x 14				
N23									0.110	x 22	0.119	x 24	0.110	x 22	0.097	x 19	0.072	x 14	0.139	x 28				
avg	**0.173**	**0.198**	**0.110**	**0.170**	**0.255**	**0.160**	**0.085**	**x 17**	**0.107**	**x 21**	**0.120**	**x 24**	**0.124**	**x 25**	**0.100**	**x 20**	**0.110**	**x 22**	**0.122**	**x 24**		**x 0**		**x 0**

Surface Water												
Year	2018			2019	2020				2021			
SITE	Q1	Q2	Q2	Q1	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
KR	ND					ND			ND			
CVC	ND					ND			ND			
FKC	ND					0.0008			ND			
KD Main	ND								4/21/2021			
KD-AE-02									ND			
KD-03									0.0110			
CA AQ	ND								ND			
Blended Water												
EOC	ND				ND 0.010 0.018	0.014 0.022 0.013	0.015 0.013 0.008	0.015 0.011 0.035	0.0038 0.014 0.021	6/16/2021		
Syc Check (blend)			0.029	0.012		0.024 0.017 0.018	0.017 0.020 ND	ND N/A ND	0.022 ND 0.016	0.013		

In-Lieu						
Year	2020		2021			
SITE	Q3	Q4	Q1	Q2	Q3	Q4
D-1	0.480					
D-2	0.730					
D-3	0.201	0.145				
D-4	0.175					
D-5	0.055					

Total Wells	86
Wells sampled -2021 Q1	79
Wells sampled -2021 Q2	36
Wells over limit - 2021 Q1	53
Wells over limit - 2021 Q2	34
Wells sampled -2020 Q1	61
Wells sampled -2020 Q2	78
Wells sampled -2020 Q3	78
Wells sampled -2020 Q4	20
Wells over limit - 2020 Q1	36
Wells over limit - 2020 Q2	52
Wells over limit - 2020 Q3	49
Wells over limit - 2020 Q4	18
Wells over limit - 2019 Q1	8
Wells over limit - 2018 Q1	29
Wells over limit - 2018 Q2	45

out of service/currently not operational
ND = non-detect
Est. MDL when < 0.005
Pending results (2)

Q1 = 2018 Quarter 1 samples; Taken March 2018.
Q2 = 2018 Quarter 2 samples; Taken June/July 2018.
Q1 = 2019 Quarter 1 samples; Taken January 2019.
Q1 = 2020 Quarter 1 samples; Taken March/April/May 2020.
Q2 = 2020 Quarter 2 samples; Taken June/July/August 2020.
Q3 = 2020 Quarter 3 samples; Taken September/October/November 2020.
Q4 = 2020 Quarter 4 samples; Taken December 2020/January 2021/February 2021.
Q1 = 2021 Quarter 1 samples; Taken March/April/May 2021.
*Dates represent when sample was taken; Results expected after 15 business days.
1,2,3-TCP standard MCL = 0.005 ug/L.
BC Labs MDL = 0.005 ug/L; Any result below the MDL is ND.
APPL Labs MDL = 0.003 ug/L; Any result between the MCL and MDL is estimated.
FGL MDL = 0.00063 ug/L; Any result between the MCL and MDL is estimated; Any result below the MDL is ND.

Year (TEJON WELLS - 29)	2018							2019		2020								2021							
		COMPARE		COMPARE																					
Well	Q1 (FGL)	Q2 (FGL)	Q2 (BC)	Q2 (APPL)	Q2 (FGL)	Q2 (BC)		Q1 (APPL)	Strength of Q1	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4
71		ND								ND	x	0.001	x 0	0.004	x 1			0.006	x 1	0.003	x 1				
72	ND	0.005								ND	x	0.006	x 1	0.006	x 1			0.006	x 1	0.007	x 1				
73		0.003								0.004	x 1	0.009	x 2	0.007	x 1			0.008	x 2	0.011	x 2				
74		ND										ND	x	ND	x			ND	x	0.001	x 0				
75		ND								0.003	x 1	0.004	x 1	0.004	x 1			0.005	x 1		x				
76	ND	ND								ND	x	ND	x	0.003	x 1			0.006	x 1	0.008	x 2				
77		ND								ND	x	ND	x	ND	x			ND	x		x				
78		ND								ND	x	0.003	x 1	ND	x			ND	x		x				
79		0.009								0.003	x 1	0.015	x 3	0.010	x 2			0.010	x 2	0.017	x 3				
80	ND	0.004								0.004	x 1	0.010	x 2	0.001	x 0			0.004	x 1		x				
81		0.001								ND	x	ND	x	ND	x			0.001	x 0		x				
82																		0.005	x 1		x				
83		ND								ND	x	ND	x	0.002	x 0			0.002	x 0		x				
84	0.011	0.012										0.008	x 2	0.006	x 1			0.011	x 2	0.024	x 5				
86		0.005										0.009	x 2	0.003	x 1			0.006	x 1		x				
87		0.010								0.011	x 2	0.054	x 11	0.014	x 3			0.049	x 10		x				
88		0.157								0.163	x 33	0.437	x 87	0.261	x 52			0.155	x 31	0.408	x 82				
89		0.014								0.013	x 3	0.026	x 5	0.027	x 5			0.051	x 10		x				
90	ND	0.003								ND	x	0.006	x 1	0.003	x 1			0.004	x 1		x				
91																									
92	0.213	0.287		0.210	0.313	0.230				0.092	x 18	0.265	x 53	0.260	x 52	0.288	x 58	0.204	x 41	0.258	x 52				
93		0.027								0.020	x 4	0.041	x 8	0.037	x 7			0.032	x 6	0.053	x 11				
94	0.019	0.020								0.012	x 2	0.022	x 4	0.017	x 3			0.017	x 3	0.024	x 5				
95																		0.014	x 3		x				
96	0.031	0.019	0.008							0.013	x 3	0.007	x 1	0.009	x 2			0.010	x 2	0.009	x 2				
98	0.014	0.017								0.010	x 2	0.012	x 2	0.011	x 2			0.010	x 2	0.011	x 2				
99	0.057	0.042	0.016	0.016	0.039	0.016				0.015	x 3	0.020	x 4	0.018	x 4	0.012	x 2	0.016	x 3	0.018	x 4				
100	0.025	0.035								0.014	x 3	0.019	x 4	0.021	x 4			0.015	x 3	0.019	x 4				
101								0.019	x 4	0.026	x 5	0.030	x 6	0.025	x 5	0.028	x 6	0.026	x 5	0.028	x 6				
avg	**0.053**	**0.037**	**0.012**	**0.113**	**0.176**	**0.123**		**0.019**	x **4**	**0.027**	x **5**	**0.048**	x **10**	**0.034**	x **7**	**0.109**	x	**0.027**	x **5**	**0.056**	x **11**		x **0**		x

Year		2018						2019		2020								2021							
			COMPARE		COMPARE																		
	Well	Q1 (FGL)	Q2 (FGL)	Q2 (BC)	Q2 (APPL)	Q2 (FGL)	Q2 (BC)	Q1 (APPL)	Strength of Q1	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4	Q1 (FGL)	Strength of Q1	Q2 (FGL)	Strength of Q2	Q3 (FGL)	Strength of Q3	Q4 (FGL)	Strength of Q4
SYCAMORE WELLS - 34	1	0.010	0.010							0.004	x 1	0.024	x 5	0.029	x 6	0.035	x 7	0.033	x 7	0.046	x 9				
	2		0.002									0.007	x 1	0.008	x 2			0.022	x 4		x				
	4		ND							ND	x	0.014	x 3	0.004	x 1			0.022	x 4		x				
	5		0.002							0.002	x 0	0.017	x 3	0.020	x 4			0.015	x 3		x				
	6		0.030									0.012	x 2	0.007	x 1			0.007	x 1		x				
	7		0.007									0.010	x 2	0.006	x 1			0.006	x 1		x				
	8		0.002							0.006	x 1	0.012	x 2	0.015	x 3	0.013	x 3	0.013	x 3	0.020	x 4				
	9		0.019							0.013	x 3	0.034	x 7	0.037	x 7			0.033	x 7		x				
	10		0.013									ND	x	ND	x			0.004	x 1		x				
	11	0.057	0.018							0.007	x 1	0.008	x 2	0.008	x 2			0.007	x 1		x				
	12	0.034	0.036	0.015	0.013	0.037	0.017					ND	x	0.007	x 1			0.010	x 2		x				
	13		0.005									ND	x	ND	x			ND	x		x				
	14		0.008							0.003	x 1	0.004	x 1	0.003	x 1	ND	x	0.004	x 1		x				
	15		0.001									ND	x	ND	x			ND	x		x				
	16		0.001									ND	x	ND	x			ND	x		x				
	17		ND									ND	x	ND	x			ND	x		x				
	18		ND									ND	x	ND	x			ND	x		x				
	20	0.009	0.002	ND						0.005	x 1	0.015	x 3	0.024	x 5	0.021	x 4	0.029	x 6		x				
	21		0.006							0.023	x 5	0.002	x 0	0.001	x 0			0.002	x 0		x				
	22		0.041							0.017	x 3	0.031	x 6	0.022	x 4	0.022	x 4	0.020	x 4	0.022	x 4				
	23		0.060							0.024	x 5	0.027	x 5	0.019	x 4	0.021	x 4	0.017	x 3		x				
	24	0.131	0.074		0.029	0.067	0.034			0.006	x 1	0.015	x 3	0.012	x 2	0.011	x 2	0.009	x 2	0.011	x 2				
	25		0.017							0.003	x 1	0.007	x 1	0.006	x 1			0.004	x 1		x				
	26		0.019							0.003	x 1	0.004	x 1	0.001	x 0			0.004	x 1		x				
	28	ND	ND							0.005	x 1	0.007	x 1	0.007	x 1	0.006	x 1								
	29		ND							0.003	x 1	0.002	x 0	0.001	x 0			ND	x		x				
	31	0.028	0.020							0.004	x 1	0.002	x 0	ND	x			0.003	x 1		x				
	32											0.001	x 0	ND	x			ND	x		x				
	33		0.004									0.001	x 0	0.002	x 0			ND	x		x				
	34																								
	35		ND							ND	x	ND	x	ND	x			ND	x		x				
	36		0.018									ND	x	0.002	x 0			ND	x		x				
	37		0.029							0.004	x 1	0.003	x 1	0.002	x 0			0.003	x 1		x				
	38	ND	ND					ND	x	ND	x	ND	x	ND	x	ND	x	ND	x		x				
	avg	**0.045**	**0.018**	**0.015**	**0.021**	**0.052**	**0.026**	**ND**	x	**0.008**	x **2**	**0.011**	x **2**	**0.011**	x **2**	**0.018**	x **4**	**0.013**	x **3**	**0.025**	x **5**		x **0**		x **0**

Appendix B Monthly Operations Breakdown

	Year/Month		Total Imported Water[2]	Grower Deliveries[2]	MWD Deliveries (Total)[3]	MWD Deliveries via intertie pipeline[1]	Total Well Production[2]	Well Production During Intertie Deliveries
3/1/2002	2002	Mar	133	11,664	0	0	12,765	-
4/1/2002		Apr	8,319	17,371	0	0	11,224	-
5/1/2002		May	9,712	20,382	0	0	12,096	-
6/1/2002		Jun	14,251	20,985	0	0	9,116	-
7/1/2002		Jul	17,185	22,344	0	0	6,700	-
8/1/2002		Aug	9,841	18,803	0	0	11,615	-
9/1/2002		Sep	12,912	14,387	0	0	2,369	-
10/1/2002		Oct	10,979	10,401	0	0	0	-
11/1/2002		Nov	6,016	3,627	0	0	0	-
12/1/2002		Dec	3,845	937	0	0	527	-
1/1/2003		Jan	3,434	3,073	5,795	5795	6,430	6,430
2/1/2003		Feb	2,374	4,080	5,688	5688	7,677	7,677
3/1/2003	2003	Mar	373	8,176	897	897	9,975	9,975
4/1/2003		Apr	19,028	11,693	0	0	6,172	-
5/1/2003		May	35,959	16,238	0	0	0	-
6/1/2003		Jun	30,341	22,131	0	0	0	-
7/1/2003		Jul	22,852	21,063	0	0	125	-
8/1/2003		Aug	18,741	16,369	0	0	0	-
9/1/2003		Sep	15,909	15,523	0	0	0	-
10/1/2003		Oct	12,367	11,548	0	0	0	-
11/1/2003		Nov	4,952	4,456	0	0	27	-
12/1/2003		Dec	5,770	1,645	0	0	351	-
1/1/2004		Jan	2,005	1,437	0	0	0	-
2/1/2004		Feb	2,918	2,664	0	0	0	-
3/1/2004	2004	Mar	11,031	10,097	0	0	0	-
4/1/2004		Apr	11,148	18,428	0	0	8,828	-
5/1/2004		May	9,950	22,633	0	0	13,668	-
6/1/2004		Jun	11,823	21,052	1,664	1664	13,169	13,169
7/1/2004		Jul	9,862	19,301	1,982	1982	13,151	13,151
8/1/2004		Aug	10,264	20,349	2,829	2829	13,063	13,063
9/1/2004		Sep	7,616	14,956	11,630	5098	13,142	13,142
10/1/2004		Oct	2,430	8,022	13,625	4293	10,174	10,174
11/1/2004		Nov	2,059	3,345	6,858	4957	7,819	7,819
12/1/2004		Dec	0	1,835	4,689	4689	6,967	6,967
1/1/2005		Jan	9,033	889	0	0	144	-
2/1/2005		Feb	23,288	2,755	0	0	0	-
3/1/2005	2005	Mar	28,944	7,525	0	0	0	-
4/1/2005		Apr	34,450	14,410	0	0	0	-
5/1/2005		May	27,284	13,893	0	0	0	-
6/1/2005		Jun	32,363	19,666	0	0	0	-
7/1/2005		Jul	27,949	21,315	0	0	0	-
8/1/2005		Aug	23,350	21,560	0	0	0	-
9/1/2005		Sep	16,585	15,575	0	0	0	-
10/1/2005		Oct	9,269	8,566	0	0	0	-
11/1/2005		Nov	9,037	5,133	0	0	174	-
12/1/2005		Dec	2,198	1,221	0	0	0	-
1/1/2006		Jan	17,908	2,165	0	0	0	-
2/1/2006		Feb	24,608	8,074	0	0	0	-
3/1/2006		Mar	21,442	5,024	0	0	0	-
4/1/2006		Apr	22,285	9,017	0	0	0	-
5/1/2006		May	31,033	17,544	0	0	0	-

	Year/Month		Total Imported Water[2]	Grower Deliveries[2]	MWD Deliveries (Total)[3]	MWD Deliveries via intertie pipeline[1]	Total Well Production[2]	Well Production During Intertie Deliveries
6/1/2006		Jun	33,817	21,311	0	0	0	-
7/1/2006		Jul	26,950	21,552	0	0	0	-
8/1/2006	2006	Aug	23,647	19,512	0	0	0	-
9/1/2006		Sep	18,062	14,774	0	0	0	-
10/1/2006		Oct	9,590	9,601	0	0	0	-
11/1/2006		Nov	6,646	5,866	0	0	292	-
12/1/2006		Dec	5,609	2,049	0	0	0	-
1/1/2007		Jan	17,138	4,037	0	0	0	-
2/1/2007		Feb	3,374	3,939	0	0	997	-
3/1/2007		Mar	537	9,082	2,540	2540	12,664	12,664
4/1/2007		Apr	3,102	15,905	1,254	1254	14,900	14,900
5/1/2007		May	8,541	21,173	598	598	15,079	15,079
6/1/2007		Jun	10,188	21,207	485	485	14,372	14,372
7/1/2007		Jul	8,850	22,536	500	500	14,452	14,452
8/1/2007	2007	Aug	7,043	20,082	701	701	14,432	14,432
9/1/2007		Sep	3,471	15,347	1,531	1531	14,329	14,329
10/1/2007		Oct	134	9,405	5,092	5092	14,639	14,639
11/1/2007		Nov	2,014	6,788	5,893	5893	11,460	11,460
12/1/2007		Dec	0	1,666	5,631	5631	8,223	8,223
1/1/2008		Jan	0	2,206	8,715	8715	10,837	10,837
2/1/2008		Feb	3,819	4,396	5,758	5758	6,797	6,797
3/1/2008		Mar	9,302	11,893	4,710	4710	8,352	8,352
4/1/2008		Apr	7,342	18,011	1,054	1054	13,034	13,034
5/1/2008		May	9,361	20,930	604	604	14,499	14,499
6/1/2008		Jun	10,526	21,908	783	783	13,873	13,873
7/1/2008		Jul	10,571	21,399	979	979	13,591	13,591
8/1/2008	2008	Aug	8,614	17,613	1,577	1577	13,502	13,502
9/1/2008		Sep	6,262	15,275	1,819	1819	12,274	12,274
10/1/2008		Oct	1,831	12,024	3,102	3102	13,071	13,071
11/1/2008		Nov	105	6,361	5,956	5956	12,356	12,356
12/1/2008		Dec	0	207	2,545	2545	3,628	3,628
1/1/2009		Jan	0	1,300	9,331	9331	10,906	10,906
2/1/2009		Feb	0	2,260	7,869	7869	10,843	10,843
3/1/2009		Mar	1,078	9,123	3,528	3528	12,813	12,813
4/1/2009		Apr	8,003	15,421	0	0	9,929	-
5/1/2009		May	37,932	19,382	0	0	2,894	-
6/1/2009		Jun	20,110	18,887	1,771	1771	10,284	10,284
7/1/2009		Jul	8,690	21,011	83	83	14,352	14,352
8/1/2009	2009	Aug	5,577	17,560	327	327	13,925	13,925
9/1/2009		Sep	12,062	15,453	8,568	8568	13,042	13,042
10/1/2009		Oct	12,147	9,897	8,858	8858	9,376	9,376
11/1/2009		Nov	27,315	5,672	10,625	9125	0	-
12/1/2009		Dec	0	732	5,488	5488	6,716	6,716
1/1/2010		Jan	0	739	17,999	8847	9,684	9,684
2/1/2010		Feb	918	1,245	24,809	8523	8,863	8,863
3/1/2010		Mar	8,344	6,737	0	0	2,442	-
4/1/2010		Apr	20,965	9,330	13,950	5768	0	-
5/1/2010		May	38,462	14,638	23,836	8903	0	-
6/1/2010		Jun	30,992	21,252	1,543	717	0	-
7/1/2010		Jul	38,323	20,141	0	0	0	-
8/1/2010	10	Aug	41,006	20,413	0	0	0	-

	Year/Month		Total Imported Water[2]	Grower Deliveries[2]	MWD Deliveries (Total)[3]	MWD Deliveries via intertie pipeline[1]	Total Well Production[2]	Well Production During Intertie Deliveries
9/1/2010	20	Sep	35,894	15,924	0	0	0	-
10/1/2010		Oct	26,979	9,281	0	0	0	-
11/1/2010		Nov	13,408	5,252	0	0	0	-
12/1/2010		Dec	1,565	511	0	0	230	-
1/1/2011		Jan	10,907	1,239	0	0	51	-
2/1/2011		Feb	13,549	3,517	8,038	2313	0	-
3/1/2011	2011	Mar	12,143	4,649	0	0	3	-
4/1/2011		Apr	23,286	11,795	15,525	2674	0	-
5/1/2011		May	32,034	15,714	11,858	7744	0	-
6/1/2011		Jun	30,341	18,181	4,063	3334	3	3
7/1/2011		Jul	31,651	21,487	0	0	0	-
8/1/2011		Aug	29,570	19,505	0	0	0	-
9/1/2011		Sep	24,722	15,097	0	0	158	-
10/1/2011		Oct	19,002	9,964	0	0	0	-
11/1/2011		Nov	13,519	5,047	0	0	0	-
12/1/2011		Dec	9,264	1,150	0	0	0	-
1/1/2012		Jan	10,422	1,936	0	0	0	-
2/1/2012		Feb	10,692	4,065	0	0	0	-
3/1/2012	2012	Mar	240	8,311	6,495	6495	15,439	15,439
4/1/2012		Apr	641	11,325	3,425	3425	14,803	14,803
5/1/2012		May	8,926	21,127	90	90	13,347	13,347
6/1/2012		Jun	21,826	20,015	0	0	0	-
7/1/2012		Jul	22,688	20,653	0	0	0	-
8/1/2012		Aug	21,687	19,552	0	0	0	-
9/1/2012		Sep	15,116	14,035	0	0	0	-
10/1/2012		Oct	6,251	12,384	0	0	5,480	-
11/1/2012		Nov	2,499	7,123	0	0	4,632	-
12/1/2012		Dec	296	789	0	0	999	-
1/1/2013		Jan	0	2,171	10,092	0	2,228	-
2/1/2013		Feb	0	4,152	9,512	6728	11,771	11,771
3/1/2013	2013	Mar	0	8,842	5,299	5299	15,445	15,445
4/1/2013		Apr	3,402	16,819	940	940	14,786	14,786
5/1/2013		May	8,520	21,867	428	428	14,527	14,527
6/1/2013		Jun	9,554	20,358	885	885	13,560	13,560
7/1/2013		Jul	7,926	23,270	114	114	13,834	13,834
8/1/2013		Aug	7,003	19,179	17	17	13,657	13,657
9/1/2013		Sep	3,889	16,304	700	700	13,052	13,052
10/1/2013		Oct	1,200	11,566	2,623	2623	13,528	13,528
11/1/2013		Nov	1,679	7,923	6,746	6746	12,377	12,377
12/1/2013		Dec	0	2,773	8,725	8725	11,950	11,950
1/1/2014		Jan	0	5,390	6,759	6759	12,369	12,369
2/1/2014		Feb	583	7,314	5,313	5313	12,267	12,267
3/1/2014	2014	Mar	2,055	11,336	3,074	3074	13,327	13,327
4/1/2014		Apr	2,463	12,480	1,248	3248	12,527	12,527
5/1/2014		May	5,887	16,832	0	395	12,415	12,415
6/1/2014		Jun	9,110	18,070	223	2693	11,621	11,621
7/1/2014		Jul	7,658	17,690	63	1189	11,617	11,617
8/1/2014		Aug	4,914	14,709	742	2376	11,325	11,325
9/1/2014		Sep	4,703	13,602	354	2054	10,996	10,996
10/1/2014		Oct	4,222	11,133	2,499	4253	10,907	10,907
11/1/2014		Nov	2,184	4,618	6,167	7894	10,144	10,144

	Year/Month		Total Imported Water[2]	Grower Deliveries[2]	MWD Deliveries (Total)[3]	MWD Deliveries via intertie pipeline[1]	Total Well Production[2]	Well Production During Intertie Deliveries
12/1/2014		Dec	48	813	8,065	8110	8,952	8,952
1/1/2015		Jan	596	1,748	8,651	9174	10,519	10,519
2/1/2015		Feb	2,115	4,960	5,605	7568	10,367	10,367
3/1/2015	2015	Mar	4,510	11,498	1,829	4935	11,327	11,327
4/1/2015		Apr	5,119	11,497	1,304	5018	10,666	10,666
5/1/2015		May	5,131	12,863	409	4030	10,726	10,726
6/1/2015		Jun	9,694	13,769	0	2858	10,443	10,443
7/1/2015		Jul	8,128	12,399	156	3857	10,230	10,230
8/1/2015		Aug	5,328	9,362	1,011	4192	9,883	9,883
9/1/2015		Sep	5,128	8,742	2,716	5253	9,454	9,454
10/1/2015		Oct	5,128	9,700	3,870	5724	10,186	10,186
11/1/2015		Nov	4,255	5,840	7,223	8285	10,127	10,127
12/1/2015		Dec	3,900	1,525	9,306	9306	10,353	10,353
1/1/2016		Jan	0	2,600	9,506	9506	10,258	10,258
2/1/2016		Feb	0	4,480	6,098	6787	9,705	9,705
3/1/2016	2016	Mar	5,840	8,360	5,415	5626	8,550	8,550
4/1/2016		Apr	20,306	11,956	12,346	7804	0	-
5/1/2016		May	17,868	12,690	0	96	0	-
6/1/2016		Jun	10,869	17,071	0	0	5,724	-
7/1/2016		Jul	10,660	16,902	0	0	5,705	-
8/1/2016		Aug	10,038	15,709	0	0	5,528	-
9/1/2016		Sep	7,386	12,596	0	0	5,046	-
10/1/2016		Oct	6,815	9,369	0	0	2,399	-
11/1/2016		Nov	4,729	4,693	0	0	0	-
12/1/2016		Dec	962	567	0	100	52	52
1/1/2017		Jan	14,369	97	12,238	5863	0	-
2/1/2017		Feb	17,710	669	0	0	6	-
3/1/2017	2017	Mar	26,442	6,049	0	0	0	-
4/1/2017		Apr	30,468	12,412	0	0	28	-
5/1/2017		May	33,198	16,150	0	0	0	-
6/1/2017		Jun	33,876	17,876	0	0	0	-
7/1/2017		Jul	34,783	16,942	0	0	0	-
8/1/2017		Aug	34,036	16,009	0	0	0	-
9/1/2017		Sep	28,070	12,673	0	0	7	-
10/1/2017		Oct	21,727	10,139	0	0	0	-
11/1/2017		Nov	13,299	4,813	0	0	15	-
12/1/2017		Dec	10,258	2,416	0	0	0	-
1/1/2018		Jan	9,337	1,462	0	0	0	-
2/1/2018		Feb	12,860	5,546	0	0	0	-
3/1/2018	2018	Mar	5,701	2,238	4,277	4277	2,897	2,897
4/1/2018		Apr	29,266	11,040	5,813	5813	0	-
5/1/2018		May	23,897	16,064	6,421	3803	0	-
6/1/2018		Jun	12,935	17,876	0	0	5,790	-
7/1/2018		Jul	13,275	18,991	0	0	5,391	-
8/1/2018		Aug	14,441	17,661	0	0	3,401	-
9/1/2018		Sep	14,581	12,892	0	0	352	-
10/1/2018		Oct	11,868	12,125	0	0	55	-
11/1/2018		Nov	6,856	6,797	0	0	0	-
12/1/2018		Dec	1,173	722	0	0	0	-
1/1/2019		Jan	561	1,307	0	0	753	-
2/1/2019		Feb	14,588	925	0	0	0	-

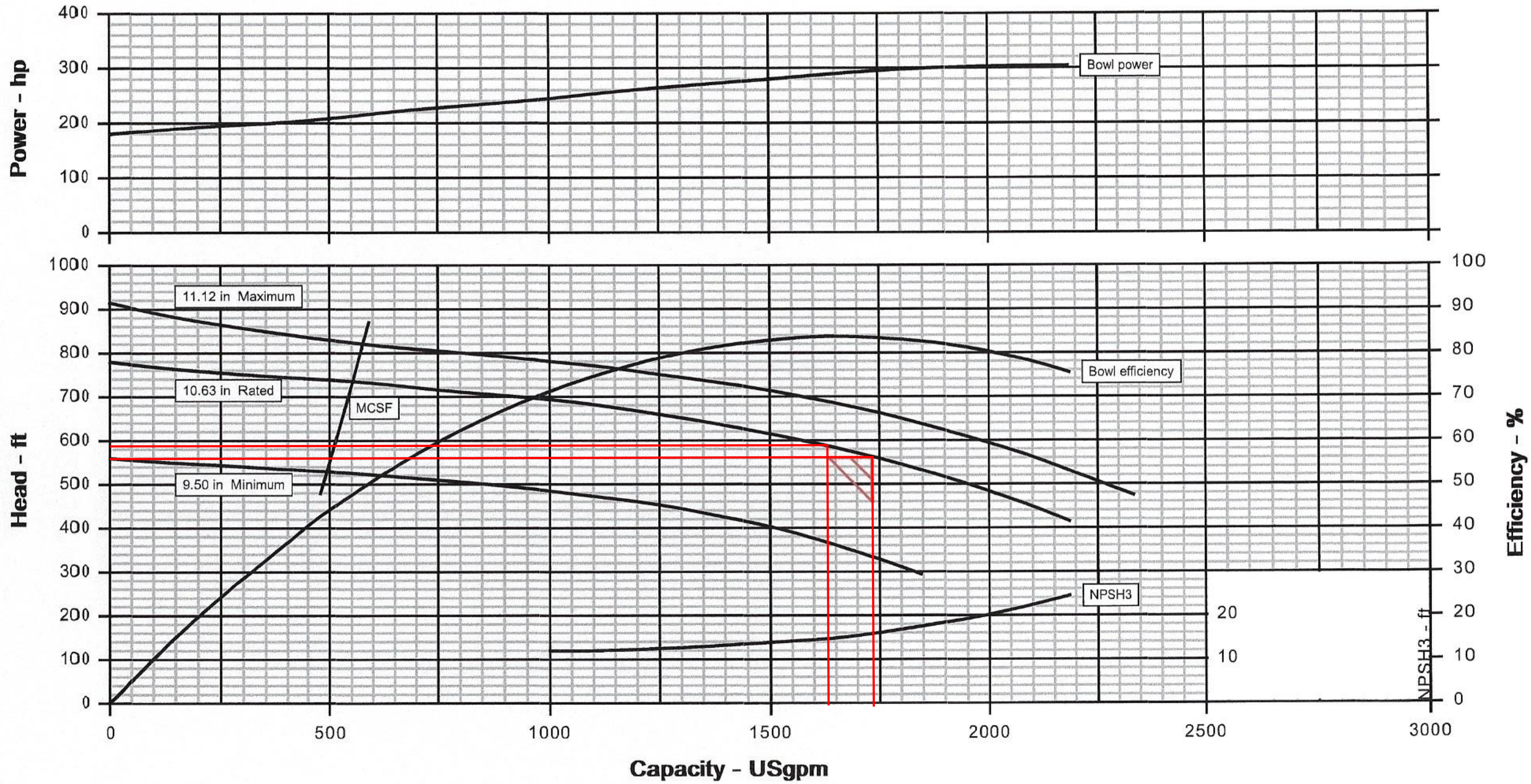
	Year/Month		Total Imported Water[2]	Grower Deliveries[2]	MWD Deliveries (Total)[3]	MWD Deliveries via intertie pipeline[1]	Total Well Production[2]	Well Production During Intertie Deliveries
3/1/2019	2019	Mar	22,819	3,429	0	0	8	-
4/1/2019		Apr	32,381	11,507	0	0	0	-
5/1/2019		May	27,424	9,687	0	532	0	-
6/1/2019		Jun	37,839	16,425	9,895	5150	0	-
7/1/2019		Jul	27,535	16,787	1,080	711	0	-
8/1/2019		Aug	21,694	16,849	0	0	0	-
9/1/2019		Sep	16,517	14,495	0	0	0	-
10/1/2019		Oct	13,078	10,614	0	0	0	-
11/1/2019		Nov	6,227	5,198	0	0	15	-
12/1/2019		Dec	283	229	0	0	0	-
1/1/2020		Jan	1,343	685	0	0	0	-
2/1/2020		Feb	10,030	4,617	0	0	0	-

Appendix C Well Pump Curves

Customer	: FLOWSERVE PUMP DIVISION	Capacity	: 1735.0 USgpm
Item number	: -	Head	: 562.00 ft
Service	: Pacific Irrigation	Density / Specific gravity	: - / 1.000
Flowserve reference	: 504585485	Pump speed	: 1775 rpm
Pump size & type / Stages	: 14EMM / 7	Ns / Nss	: 2316 / 9470 (US units)
Based on curve no.	: 87028718	Test tolerance	: ANSI/HI 14.6 Grade 1B
Impeller diameter	: 10.63 in	Date	: May 19, 2020

CURVES ARE APPROXIMATE, PUMP IS GUARANTEED FOR ONE SET OF CONDITIONS; CAPACITY, HEAD, AND EFFICIENCY.

Bowl performance shown below is corrected for materials, viscosity and construction.



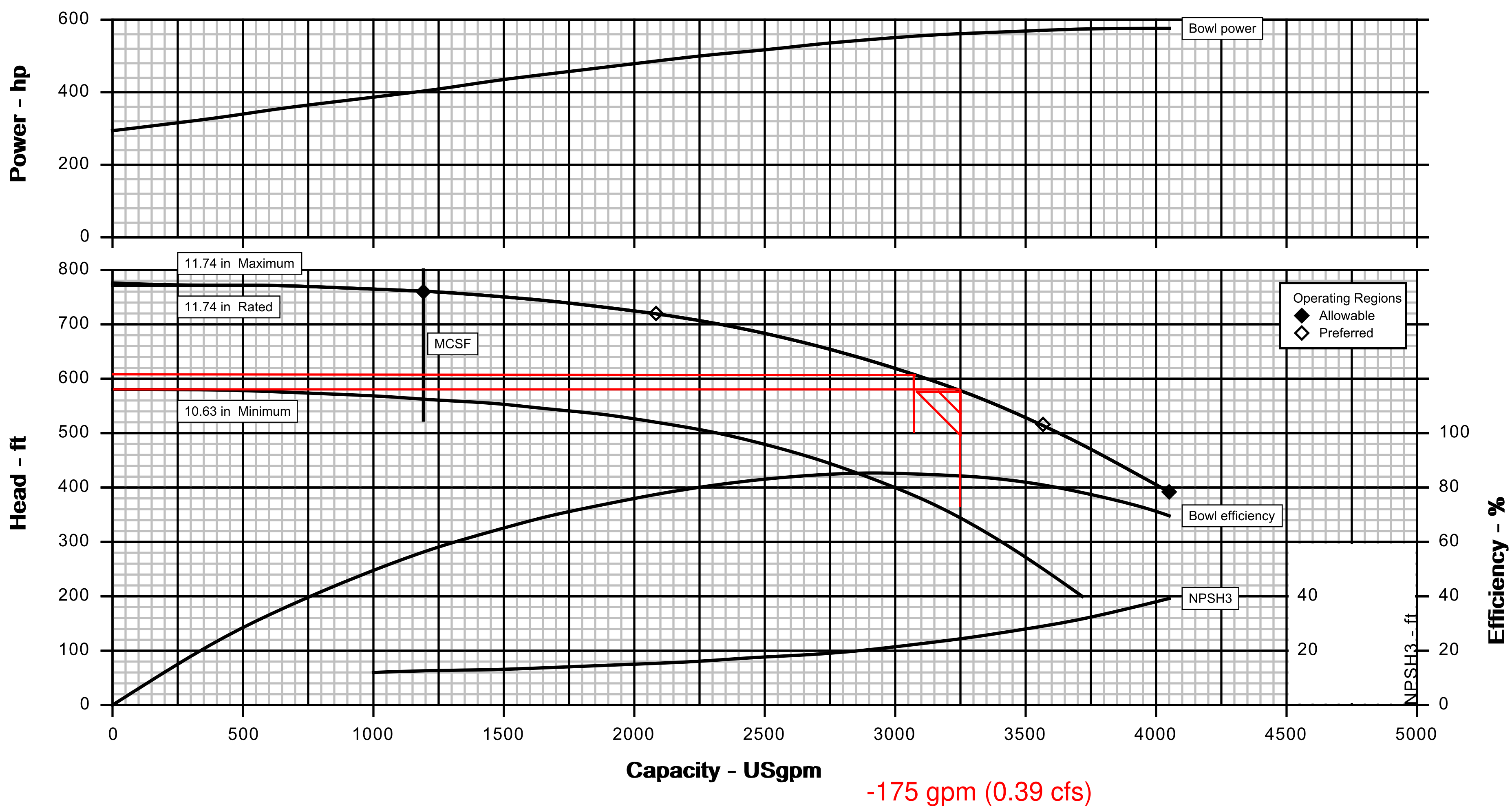
Bowl head of 563.06 ft corresponds with 562 ft head at low liquid level adjusted for elevation and friction losses.

Affinity v2.17.1

Customer	: BAKERSFIELD WELL & PUMP	Capacity	: 3250.0 USgpm
Item number	: -	Head	: 575.00 ft
Service	: -	Density / Specific gravity	: - / 0.999
Flowserve reference	: 2182165529	Pump speed	: 1775 rpm
Pump size & type / Stages	: 15EHM / 6	Ns / Nss	: 2972 / 9800 (US units)
Based on curve no.	: EC-2392	Test tolerance	: ANSI/HI 14.6 Grade 1B
Impeller diameter	: 11.74 in	Date	: March 10, 2020

CURVES ARE APPROXIMATE, PUMP IS GUARANTEED FOR ONE SET OF CONDITIONS; CAPACITY, HEAD, AND EFFICIENCY.

Bowl performance shown below is corrected for materials, viscosity and construction.



Bowl head of 578.92 ft corresponds with 575 ft head at low liquid level adjusted for elevation and friction losses.

Appendix D New Well Cost Estimate

PRELIMINARY CONSTRUCTION COST ESTIMATE FOR A TYPICAL NEW WELL

Item No.	Description	Quantity	Unit	Unit Price	Item Cost
	GENERAL				
1	Mobilization/Demobilization, Bonds, Insurance, and Permits	1	LS	$35,000	$35,000
2	Worker Protection	1	LS	$3,500	$3,500
3	Miscellaneous Facilities and Operations	1	LS	$1,500	$1,500
4	Construct Well Pad	1	LS	$40,000	$40,000
	WELL CONSTRUCTION				
5	F&I 36-Inch Diameter Conductor Casing	50	LF	$400	$20,000
6	Drill Pilot Hole (to 1,400-feet total depth)	1,320	LF	$55	$72,600
7	Perform Electric and Deviation Logs	1	LS	$4,500	$4,500
8	Perform Zone Sampling	0	EA	$12,000	$0
9	Open Hole to 30-Inch Diameter (to 1,400-feet total depth)	1,320	LF	$55	$72,600
10	F&I 18-Inch Diameter Blank Casing	590	LF	$145	$85,550
11	F&I 18-Inch Diameter Perforated Casing	720	LF	$175	$126,000
12	F&I 18-Inch Diameter 20-Foot Compression Section	1	LS	$4,500	$4,500
13	F&I 2-Inch Diameter Sounding Tube	800	LF	$12	$9,600
14	F&I 3-Inch Gravel Fill Pipe	205	LF	$16	$3,280
15	F&I Gravel Pack	1,120	LF	$35	$39,200
16	F&I Annular Seal	200	LF	$55	$11,000
17	Preliminary Development	60	HR	$325	$19,500
18	Mob/Demob Development Pump and Pump up to 40 Hours	1	LS	$25,000	$25,000
19	Additional Pump Development and Test Pumping	40	HR	$325	$13,000
20	Perform Video Log	1	LS	$1,500	$1,500
	WELL EQUIPPING				
21	Construct Well Pump Foundation	1	LS	$3,500	$3,500
22	F&I Deep Vertical Turbine Well Pump	1	LS	$50,000	$50,000
23	F&I 400HP Premium Efficiency Electric Motor	1	LS	$50,000	$50,000
24	F&I 12-Inch x 3-Inch x 1-15/16-Inch Diameter Column Pipe, Tube, and Shaft	800	LF	$150	$120,000
25	F&I Electrical Conduits and Cables	1	LS	$7,500	$7,500
26	Startup and Testing	1	LS	$1,000	$1,000
	PIPELINE				
27	F&I 12-Inch Diameter Steel Well Discharge	1	LS	$40,000	$40,000
28	F&I 12-Inch Diameter P.I.P. CL100 (SDR 41 Pipeline	100	LF	$150	$15,000
29	F&I 12-Inch Diameter Steel Discharge Pipe	1	LS	$5,000	$5,000
				TOTAL BASE BID	$879,830

Appendix E Treatment Alternative 1 Cost Estimates

Alternative 1
40 Wellhead Treatment Plants

	4-Vessel	**6-Vessel**	**8-Vessel**	**10-Vessel**	**12-Vessel**	**14-Vessel**	**16-Vessel**	**18-Vessel**	**20-Vessel**	**22-Vessel**	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	9	11	7	5	0	2	1	1	3	1	
Subtotal Construction Cost	**$14,094,000**	**$24,288,000**	**$20,050,800**	**$17,604,000**	**$0**	**$9,667,200**	**$5,490,000**	**$6,146,400**	**$20,408,400**	**$7,459,200**	$125,208,000
										Design @ 5%	$6,260,400
										CM and Inspection @ 2.5%	$3,130,200
										Environmental, Legal & Admin @ 1.5%	$1,878,120
										TOTAL	**$136,476,720**

Alternative 1
Wellhead Treatment at 7 Make-up Wells

	4-Vessel	6-Vessel	8-Vessel	10-Vessel	12-Vessel	14-Vessel	16-Vessel	18-Vessel	20-Vessel	22-Vessel	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	0	7	0	0	0	0	0	0	0	0	
Subtotal Construction Cost	**$0**	**$15,456,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$15,456,000
										Design @ 5%	$772,800
										CM and Inspection @ 2.5%	$386,400
										Environmental, Legal & Admin @ 1.5%	$231,840
										TOTAL	**$16,847,040**

Alternative 1
Treatment of 5 In Lieu Wells

	4-Vessel	6-Vessel	8-Vessel	10-Vessel	12-Vessel	14-Vessel	16-Vessel	18-Vessel	20-Vessel	22-Vessel	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	3	2	0	0	0	0	0	0	0	0	
Subtotal Construction Cost	**$4,698,000**	**$4,416,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$9,114,000
										Design @ 5%	$455,700
										CM and Inspection @ 2.5%	$227,850
										Environmental, Legal & Admin @ 1.5%	$136,710
										TOTAL	**$9,934,260**

Alternative 1
Opinion of Probable Operation and Maintenance Costs

Assumptions	
Carbon Usage Rate	0.13 lbs/1000gal
Carbon Cost	$1.85/lb
Power Unit Cost	$0.12/kWh
Pump Efficiency	70%
General Maintenance Labor Hours	66.0 hr/week
Sampling Labor	0.50 hr/sample
Months Intertie Pipeline is Active	47%
Labor Unit Cost	$52.41/hr
TCP Laboratory and Sampling (Raw Well and Combined)	34.0 sample/month
TCP Laboratory and Sampling (Skid Tracking)	1.0 sample/pair/month
GAC Changeout Labor Requirement	08.0 hr
TCP Sampling Cost	$69.00/sample
Annual Cost of Vessel Maintenance	2.50%
Present Worth 10 Year O&M Real Discount Rate	-1.10%
Present Worth 20 Year O&M Real Discount Rate	-0.50%
Present Worth 30 Year O&M Real Discount Rate	-0.30%
Present Worth 40 Year O&M Real Discount Rate	-0.30%
Present Worth 50 Year O&M Real Discount Rate	-0.30%
O&M Costs	**All Plants**
Total System Size	8,360,000 lbs
No. of 2 Vessel GAC Trains	209
Annual Production	16,056 MG/yr
Costs	
Annual Cost of Carbon Usage	$3,861,000
Annual Cost of Additional Power	$198,800
Annual Cost of Additional Labor	$259,000
Annual Cost of Additional Sampling	$95,000
Annual Cost of Vessel Maintenance	$1,959,400
Total Annual O&M Cost	**$6,373,200**
10-year Service Life O&M Costs	**$67,763,698**
20-year Service Life O&M Costs	**$134,408,455**
30-year Service Life O&M Costs	**$200,378,301**
40-year Service Life O&M Costs	**$271,286,360**
50-year Service Life O&M Costs	**$344,357,186**

Appendix F Treatment Alternative 2 Cost Estimates

Alternative 2
Opinion of Probable Construction Cost - Spreading Works Gravity Plants

	North Canal	Sycamore	Tejon	
Total Carbon Volume (lbs)	1,378,000	1,701,000	1,723,000	
Total Contactor Area (ft2)	4,900	6,050	6,160	
Contactor Area per Cell (ft2)	490	605	616	
Design Flow Rate (gpm)	29,430	36,300	36,960	
Site Construction Item	**Cost**	**Cost**	**Cost**	
Gravity contactor structure w/ inlets, underdrains, and piping	$8,641,040	$10,212,801	$10,361,947	
Initial load of carbon	$2,067,000	$2,551,500	$2,584,500	
Backwash pumping	$478,659	$546,929	$553,459	
Wash water surge tank	$250,000	$300,000	$300,000	
Control and maintenance building	$1,000,000	$1,000,000	$1,000,000	
Carbon delivery area and transfer system	$490,000	$605,000	$616,000	
Civil improvements (fencing, paving, service water system, etc.)	$250,000	$325,000	$325,000	
Subtotal	$13,176,699	$15,541,230	$15,740,906	
Mobilization (5%)	$658,835	$777,061	$787,045	
Electrical and Controls (10%)	$1,317,670	$1,554,123	$1,574,091	
Subtotal Direct Cost	$15,153,204	$17,872,414	$18,102,042	
Contingency (20%)	$3,030,641	$3,574,483	$3,620,408	
Subtotal Construction Cost	$18,183,845	$21,446,897	$21,722,451	$61,353,193
			Design @ 5%	$3,067,660
			CM and Inspection @ 2.5%	$1,533,830
			Environmental, Legal & Admin @ 1.5%	$920,298
			TOTAL	**$66,874,980**

Alternative 2
Opinion of Probable Construction Cost - 5 North Canal Wells

	4-Vessel	6-Vessel	8-Vessel	10-Vessel	12-Vessel	14-Vessel	16-Vessel	18-Vessel	20-Vessel	22-Vessel	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	0	5	0	0	0	0	0	0	0	0	
Subtotal Construction Cost	**$0**	**$11,040,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$11,040,000
										Design @ 5%	$552,000
										CM and Inspection @ 2.5%	$276,000
										Environmental, Legal & Admin @ 1.5%	$165,600
										TOTAL	**$12,033,600**

Alternative 2
Opinion of Probable Construction Cost - Treatment of 7 Replacement Wells

	4-Vessel	6-Vessel	8-Vessel	10-Vessel	12-Vessel	14-Vessel	16-Vessel	18-Vessel	20-Vessel	22-Vessel	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	0	7	0	0	0	0	0	0	0	0	
Subtotal Construction Cost	**$0**	**$15,456,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$15,456,000
										Design @ 5%	$772,800
										CM and Inspection @ 2.5%	$386,400
										Environmental, Legal & Admin @ 1.5%	$231,840
										TOTAL	**$16,847,040**

Alternative 2
Opinion of Probable Construction Cost - 5 In Lieu Wells

	4-Vessel	6-Vessel	8-Vessel	10-Vessel	12-Vessel	14-Vessel	16-Vessel	18-Vessel	20-Vessel	22-Vessel	
Total System Size in Total lbs of Carbon	80,000 lbs	120,000 lbs	160,000 lbs	200,000 lbs	240,000 lbs	280,000 lbs	320,000 lbs	360,000 lbs	400,000 lbs	440,000 lbs	
No. of 2 Vessel GAC Trains	2	3	4	5	6	7	8	9	10	11	
Maximum Flow Rate (gpm)	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	
Site Construction Item	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	
Site demolition, clearing and grubbing	$8,000	$12,000	$16,000	$20,000	$24,000	$28,000	$32,000	$36,000	$40,000	$44,000	
Purchase GAC vessels w/ carbon	$750,000	$1,125,000	$1,500,000	$1,875,000	$2,250,000	$2,625,000	$3,000,000	$3,375,000	$3,750,000	$4,125,000	
Vessel installation and testing	$40,000	$60,000	$80,000	$100,000	$120,000	$140,000	$160,000	$180,000	$200,000	$220,000	
At-grade vessel foundation	$55,000	$85,000	$117,000	$149,000	$181,000	$213,000	$245,000	$277,000	$309,000	$341,000	
Site piping modifications/additions (incl. hydraulic loop)	$200,000	$250,000	$300,000	$350,000	$400,000	$450,000	$500,000	$550,000	$600,000	$650,000	
Electrical (flow meter power, lighting)	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	$270,000	$290,000	
Backwash reclaim tank and pump	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Miscellaneous site work, vehicle drive access, drainage, fencing	$80,000	$90,000	$110,000	$130,000	$150,000	$170,000	$190,000	$210,000	$230,000	$250,000	
Mobilization (5%)	$62,000	$88,000	$114,000	$140,000	$166,000	$192,000	$218,000	$244,000	$270,000	$296,000	
Subtotal Direct Cost	$1,305,000	$1,840,000	$2,387,000	$2,934,000	$3,481,000	$4,028,000	$4,575,000	$5,122,000	$5,669,000	$6,216,000	
Contingency (20%)	$261,000	$368,000	$477,400	$586,800	$696,200	$805,600	$915,000	$1,024,400	$1,133,800	$1,243,200	
Subtotal Per-Plant Construction Cost	$1,566,000	$2,208,000	$2,864,400	$3,520,800	$4,177,200	$4,833,600	$5,490,000	$6,146,400	$6,802,800	$7,459,200	
Treatment Plant Quantity	3	2	0	0	0	0	0	0	0	0	
Subtotal Construction Cost	**$4,698,000**	**$4,416,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$9,114,000
										Design @ 5%	$455,700
										CM and Inspection @ 2.5%	$227,850
										Environmental, Legal & Admin @ 1.5%	$136,710
										TOTAL	**$9,934,260**

Alternative 2
Opinion of Probable Operation and Maintenance Costs

Assumptions	Gravity	Wellhead	
Carbon Usage Rate	0.16 lbs/1000gal	0.13 lbs/1000gal	
Carbon Cost	$1.85/lb	$1.85/lb	
Power Unit Cost	$0.12/kWh	$0.12/kWh	
Pump Efficiency	70%	70%	
General System Operation Labor Hours	55.0 hr/week	8.5 hr/week	
Sampling Labor	0.25 hr/sample	0.50 hr/sample	
Months Intertie Pipeline is Active	47%	47%	
Labor Unit Cost	$52.41/hr	$52.41/hr	
TCP Laboratory and Sampling (Raw Well and Combined)	1.0 sample/month	33.0 sample/month	
TCP Laboratory and Sampling (Cell/Vessel Tracking)	1.0 sample/cell/month	1.0 sample/pair/month	
GAC Changeout Labor Requirement	24.0 hr	08.0 hr	
TCP Sampling Cost	$69.00/sample	$69.00/sample	
Annual Cost of Vessel Maintenance	1.50%	2.50%	
Present Worth 10 Year O&M Real Discount Rate	-1.10%	-1.10%	
Present Worth 20 Year O&M Real Discount Rate	-0.50%	-0.50%	
Present Worth 30 Year O&M Real Discount Rate	-0.30%	-0.30%	
Present Worth 40 Year O&M Real Discount Rate	-0.30%	-0.30%	
Present Worth 50 Year O&M Real Discount Rate	-0.30%	-0.30%	
O&M Costs	**3 Gravity Plants**	**17 Wellhead Plants**	**Total**
Total System Size	4,802,000 lbs	1,920,000 lbs	
No. of Contactor Cells / Vessel Pairs	30	48	
Annual Production	13,551 MG/yr	2,505 MG/yr	
Costs			
Annual Cost of Carbon Usage	$4,011,000	$602,000	$4,613,000
Annual Cost of Additional Power	$167,800	$31,000	$198,800
Annual Cost of Additional Labor	$169,000	$42,000	$211,000
Annual Cost of Additional Sampling	$12,000	$32,000	$44,000
Annual Cost of Maintenance	$766,900	$450,000	$1,216,900
Total Annual O&M Cost	**$5,126,700**	**$1,157,000**	**$6,283,700**
10-year Service Life O&M Costs	**$54,510,160**	**$12,301,920**	**$66,812,080**
20-year Service Life O&M Costs	**$108,120,227**	**$24,400,707**	**$132,520,933**
30-year Service Life O&M Costs	**$161,187,384**	**$36,376,968**	**$197,564,352**
40-year Service Life O&M Costs	**$218,226,916**	**$49,249,721**	**$267,476,637**
50-year Service Life O&M Costs	**$277,006,212**	**$62,515,105**	**$339,521,316**

Appendix G Treatment Alternative 3 Cost Estimates

Alternative 3
Opinion of Probable Construction Cost

	Intertie Plant
Total Carbon Volume (lbs)	4,400,000
Total Filter Adsorber Area (ft2)	26,180
Filter Adsorber Area per Cell (ft2)	1,310
Design Flow Rate (gpm)	78,545

Site Construction Item	Cost	
Gravity filter adsorber structure w/ underdrains and piping	$34,029,712	
Initial load of carbon	$6,600,000	
Surface wash system	$3,248,838	
Air scour system	$3,205,951	
Backwash pumping	$965,455	
Wash water surge tank	$750,000	
Control and maintenance building	$1,000,000	
Carbon delivery area and transfer system	$2,618,000	
Coagulant and polymer feed systems	$500,000	
Lined washwater and solids drying lagoons (15 acres)	$13,046,070	
Civil improvements (fencing, paving, service water system, etc.)	$1,000,000	
Subtotal	$66,964,025	
Mobilization (5%)	$3,348,201	
Electrical and controls (10%)	$6,696,403	
Subtotal Direct Cost	$77,008,629	
Contingency (20%)	$15,401,726	
Subtotal Construction Cost	$92,410,355	$92,410,355
	Design @ 5%	$4,620,518
	CM and Inspection @ 2.5%	$2,310,259
	Environmental, Legal & Admin @ 1.5%	$1,386,155
	TOTAL	**$100,727,287**

PROVOST & PRITCHARD CONSULTING GROUP
An Employee Owned Company

PRELIMINARY
ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

PRELIMINARY

Arvin Edison Water Storage District
TCP Mitigation Feasibility Study
Planning/Conceptual Level Costs

6/9/2021 DRAFT

Item No.	Item Description	Quantity	Unit	Unit Price	Amount [3]
FIELD COSTS [12]					
	Canal Improvements				
1	Check Structures	2	LS	$ 750,000	$ 1,500,000
2	Bypass Pipeline (48", RGRCP)	315	LF	$ 500	$ 158,000
3	48" Turnout Gate	2	EA	$ 50,000	$ 100,000
4	Demo and Fill in Existing Emergency Spillway	1	LS	$ 17,000	$ 17,000
5	Construct New Emergency Spillway	64	CY	$ 2,000	$ 128,000
				Subtotal	**$ 1,903,000**
	Pump Station				
6	Structure Earthwork	1	LS	$ 20,000	$ 20,000
7	Concrete Pump Structure	1	LS	$ 1,309,000	$ 1,309,000
8	Motor & Pumps	6	EA	$ 187,000	$ 1,122,000
9	30" Discharge Pipe and Appurtenances	1	LS	$ 352,000	$ 352,000
10	Electrical	1	LS	$ 869,000	$ 869,000
				Subtotal	**$ 3,672,000**
	Basin Work				
11	Fill for Treatment Pad	53,100	CY	$ 15	$ 797,000
12	Construct New Basin Levee on North Side	54,000	CY	$ 15	$ 810,000
13	Land Acquisition	17	AC	$ 25,000	$ 425,000
14	Demo and Reconstruct Perimeter Fence on North Side	1,885	LF	$ 18	$ 34,000
				Subtotal	**$ 2,066,000**
			FIELD COSTS SUBTOTAL		**$ 7,641,000**
GENERAL CONDITIONS [4]					
15	Mobilization/Demobilization, Bonds and Insurance and Construction Permits	5.0	%	$ 7,641,000	$ 382,000
16	Worker and Public Protection	0.5	%	$ 7,641,000	$ 38,000
17	Dust Control Plan & Implementation	0.5	%	$ 7,641,000	$ 38,000
18	SWPPP Plan & Implementation	2.0	%	$ 7,641,000	$ 153,000
19	Protect in Place Existing Facilities	0.5	%	$ 7,641,000	$ 38,000
		8.5%	**GENERAL CONDITIONS SUBTOTAL**		**$ 649,000**
NON-CONTRACT COSTS [5]					
20	Data Collection & Design [8]	10.0	%	$ 8,290,000	$ 829,000
21	Permitting & Compliance [9]	10.0	%	$ 8,290,000	$ 829,000
22	Construction Management [10]	14.0	%	$ 8,290,000	$ 1,161,000
		34.0%	**NON-CONTRACT SUBTOTAL**		**$ 2,819,000**
				PROJECT TOTAL	**$ 11,109,000**
	Preliminary Level Overall Project Contigency [11]	30.0	%	**$ 11,109,000**	$ 3,333,000
			PRELIMINARY COST W/ CONTIGENCY		**$ 14,442,000**

Notes & Assumptions:

[1] This preliminary level estimate represents the opinion of probable cost based on the engineer's experience with prior projects and cost sources such as RS Means.
[2] Costs presume work will be publically bid as a public works project.
[3] Amount totals rounded up to the nearest one-thousand dollars.
[4] Percentages are of the total Field Costs.
[5] Percentages are sum of Field Costs & General Conditions.
[6] Construction schedule may impact construction cost.
[7] Data Collection & Design includes: survey, field investigations, geotechnical investigation, reporting & legal review, design, specifications and bidding.
[8] Permitting & Compliance includes: NEPA, CEQA, federal & state ESA, Air Pollution Control District, cultural resources, land clearances, mitigation measures & legal review.
[9] out.
[10] Preliminary level contingency typically ranages from 20 to 50%.

Alternative 3
Opinion of Probable Operation and Maintenance Costs (0.5 lbs/1,000 gals)

Assumptions	
Carbon Usage Rate	0.52 lbs/1000gal
Carbon Cost	$1.85/lb
Power Unit Cost	$0.12/kWh
Pump Efficiency	80%
General System Operation Labor Hours	40.0 hr/week
Sampling Labor	0.50 hr/sample
Months Intertie Pipeline is Active	47%
Labor Unit Cost	$52.41/hr
TCP Laboratory and Sampling (Raw Well and Combined)	34.0 sample/month
TCP Laboratory and Sampling (Contactor Cell Tracking)	4.0 sample/cell/month
GAC Changeout Labor Requirement	24.0 hr
TCP Sampling Cost	$69.00/sample
Annual Cost of Maintenance	1.50%
Present Worth 10 Year O&M Real Discount Rate	-1.10%
Present Worth 20 Year O&M Real Discount Rate	-0.50%
Present Worth 30 Year O&M Real Discount Rate	-0.30%
Present Worth 40 Year O&M Real Discount Rate	-0.30%
Present Worth 50 Year O&M Real Discount Rate	-0.30%
O&M Costs	**All Plants**
Total System Size	4,400,000 lbs
No. of Contactor Cells	20
Annual Production	7,934 MG/yr
Costs	
Annual Cost of Carbon Usage	$7,633,000
Annual Cost of Additional Power	$112,100
Annual Cost of Additional Labor	$149,000
Annual Cost of Additional Sampling	$44,000
Annual Cost of Vessel Maintenance	$1,079,900
Annual Cost of Coagulant	$100,800
Total Annual O&M Cost	**$9,118,800**
10-year Service Life O&M Costs	**$96,956,569**
20-year Service Life O&M Costs	**$192,312,155**
30-year Service Life O&M Costs	**$286,702,073**
40-year Service Life O&M Costs	**$388,157,607**
50-year Service Life O&M Costs	**$492,707,637**

Appendix H TCP Revenue Impacts

ARVIN-EDISON WATER STORAGE DISTRICT

2022-2035 CUMULATION OF REGULATION FEES BASED ON SURROGATE HYDROLOGY

ESTIMATED PAST DAMAGES: 2018 - 2021

Year			CPI	Activity - AF				Delivered Fees		Returned Fees		Wheeling Fees		WQSA Credit						Total	
#	Actual	Type	(all urban)	Delivered	Returned	WQSA	Kern Delta	Rate-$/AF	Subtotal	Rate-$/AF	Subtotal	Rate-$/AF	Subtotal	Beginning	Added	Used	Ending	Rate-$/AF	Subtotal	Annual	Cumulative
1	2018	2018	149.9	0		0		$ 68.78			$ -							$ 55.81	$ -	$ -	$ -
2	2019	2019	154.2	50,000		30,000		$ 70.75	$ 3,537,500		$ -			65,781	30,000	50,000	45,781	$ 57.41	$ (2,870,500)	$ 667,000	$ 667,000
3	2020	2020	158.5	0	5,030	0		$ 72.72		$ 49.53	$ 249,136			45,781	0	0	45,781	$ 59.01	$ -	$ 249,136	$ 916,136
4	2021	2021	160.8	0	23,106	0		$ 73.78		$ 50.25	$ 1,161,077			45,781	0	0	45,781	$ 59.57	$ -	$ 1,161,077	$ 2,077,212
				0	26,894	0	31,000	$ 73.78		$ 93.71	$ 2,520,237	$ 26.93	$ 834,848.09	45,781	0	0	45,781	$ 59.57	$ -	$ 3,355,085	$ 5,432,297
			Total	50,000	55,030															$ 5,432,297	

	7%	8%			
Value of Lost Water (AF)					
WQSA	Leave Behind	KD Wheeling	Total	$/AF	Total $
0	0	0	0	$ -	$ -
30,000	3,500	0	33,500	$ 250	$ 8,375,000
0	0	0	0	$ 257	$ -
0	0	0	0	$ 261	$ 629,768
0	0	2,416	2,416		
				subtotal	$ 9,004,768

ESTIMATED FUTURE DAMAGES: 2022 - 2036

Year			CPI	Activity - AF				Delivered Fees		Returned Fees		Wheeling Fees		WQSA Credit						Total	
#	Actual	Type	(all urban)	Delivered	Returned	WQSA	Kern Delta	Rate-$/AF	Subtotal	Rate-$/AF	Subtotal	Rate-$/AF	Subtotal	Beginning	Added	Used	Ending	Rate-$/AF	Subtotal	Annual	Cumulative
5	2022	2007	125.0	1,881	24,225	0	15,020	$ 75.72	$ 142,426	$ 96.17	$ 2,329,767	$ 27.64	$ 415,110.74	45,781	0	1,881	43,900	$ 61.14	$ (114,995)	$ 2,772,309	$ 2,772,309
6	2023	2008	130.5	0	37,602	0	23,313	$ 79.05	$ -	$ 100.40	$ 3,775,375	$ 28.85	$ 672,684.82	43,900	0	0	43,900	$ 63.83	$ -	$ 4,448,060	$ 7,220,369
7	2024	2009	129.7	0	56,448	0	34,998	$ 78.57	$ -	$ 99.79	$ 5,632,837	$ 28.68	$ 1,003,641.71	43,900	0	0	43,900	$ 63.43	$ -	$ 6,636,479	$ 13,856,847
8	2025	2010	133.1	78,551	57,808	32,367	35,841	$ 80.62	$ 6,333,170	$ 102.40	$ 5,919,767	$ 29.43	$ 1,054,766.11	43,900	32,367	76,267	0	$ 65.10	$ (5,113,404)	$ 8,194,300	$ 22,051,147
9	2026	2011	134.3	61,875	0	31,446	0	$ 81.35	$ 5,033,645	$ 103.33	$ -	$ 29.69	$ -	0	31,446	31,446	0	$ 65.68	$ (4,064,167)	$ 969,478	$ 23,020,625
10	2027	2012	138.0	40,958	0	29,614	0	$ 83.59	$ 3,423,806	$ 106.17	$ -	$ 30.51	$ -	0	29,614	29,614	0	$ 67.49	$ (2,764,383)	$ 659,424	$ 23,680,049
11	2028	2013	139.8	0	12,561	25,988	7,788	$ 84.68	$ -	$ 107.56	$ 1,351,046	$ 30.91	$ 240,725.20	0	25,988	0	25,988	$ 68.37	$ -	$ 1,591,771	$ 25,271,820
12	2029	2014	141.8	0	22,435	0	13,910	$ 85.89	$ -	$ 109.10	$ 2,447,603	$ 31.35	$ 436,106.41	25,988	0	0	25,988	$ 69.35	$ -	$ 2,883,709	$ 28,155,529
13	2030	2015	142.7	0	42,080	0	26,090	$ 86.44	$ -	$ 109.79	$ 4,619,961	$ 31.55	$ 823,170.64	25,988	0	0	25,988	$ 69.79	$ -	$ 5,443,132	$ 33,598,661
14	2031	2016	143.4	0	15,604	29,999	9,674	$ 86.86	$ -	$ 110.33	$ 1,721,566	$ 31.71	$ 306,743.42	25,988	29,999	0	55,987	$ 70.13	$ -	$ 2,028,310	$ 35,626,971
15	2032	2017	145.9	45,654	0	0	0	$ 88.38	$ 4,034,832	$ 112.25	$ -	$ 32.26	$ -	55,987	0	45,654	10,333	$ 71.36	$ (3,257,725)	$ 777,107	$ 36,404,078
16	2033	2018	149.9	4,465	0	16,511	0	$ 90.80	$ 405,429	$ 115.33	$ -	$ 33.14	$ -	10,333	16,511	4,465	22,379	$ 73.31	$ (327,343)	$ 78,085	$ 36,482,164
17	2034	2019	154.2	50,000	10,975	30,000	6,805	$ 93.41	$ 4,670,310	$ 118.64	$ 1,302,050	$ 34.09	$ 231,995.24	22,379	30,000	50,000	2,379	$ 75.42	$ (3,770,810)	$ 2,433,545	$ 38,915,708
18	2035	2020	158.5	0	0	0	0	$ 96.01	$ -	$ 121.95	$ -	$ 35.05	$ -	2,379	0	0	2,379	$ 77.52	$ -	$ -	$ 38,915,708
19	2036	2021	160.8	0	50,000	0	31,000	$ 97.40	$ -	$ 123.72	$ 6,185,783	$ 35.55	$ 1,102,163.99	2,379	0	0	2,379	$ 78.64	$ -	$ 7,287,947	$ 46,203,656
			Total	283,384	329,738				$ 24,043,619		$ 35,285,756		$ 6,287,108						$ (19,412,827)	$ 46,203,656	
														ran out of WQSA credits in 2025, 2026, & 2027.					Average	$ 3,080,244	

Value of Lost Water (AF)					
WQSA	Leave Behind	KD Wheeling	Total	$/AF	Total $
0	132	1,170	1,302	$ 268	$ 348,367
0	0	1,817	1,817	$ 279	$ 507,440
0	0	2,727	2,727	$ 278	$ 757,098
32,367	5,499	2,793	40,658	$ 285	$ 11,583,068
31,446	4,331	0	35,777	$ 287	$ 10,284,362
29,614	2,867	0	32,481	$ 295	$ 9,594,087
25,988	0	607	26,595	$ 299	$ 7,957,917
0	0	1,084	1,084	$ 304	$ 328,977
0	0	2,033	2,033	$ 305	$ 620,959
29,999	0	754	30,753	$ 307	$ 9,439,074
0	3,196	0	3,196	$ 312	$ 997,991
16,511	313	0	16,824	$ 321	$ 5,397,761
30,000	3,500	530	34,030	$ 330	$ 11,231,656
0	0	0	0	$ 339	$ -
0	0	2,416	2,416	$ 344	$ 831,418
195,925	19,837	15,931	231,693	subtotal	$ 69,880,177
				Average	$ 4,658,678

Appendix I Suspension of Program

THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

Office of the General Manager

April 12, 2021 Via email: jmuhar@aewsd.org

Mr. Jeevan Muhar
Engineer-Manager
Arvin-Edison Water Storage District
20401 Bear Mountain Boulevard
Arvin, CA 93203

Dear Mr. Muhar:

2021 Request for Return of Stored Water from the Arvin-Edison Water Banking Program

Due to the initial low State Water Project allocation and projected dry hydrologic conditions for the remainder of this year, The Metropolitan Water District of Southern California (Metropolitan) is requesting the maximum return of stored water from its State Water Project groundwater banking partners, including Arvin-Edison.

Metropolitan understands, however, that Arvin-Edison's ability to return stored water to Metropolitan is now limited due to the establishment of a Maximum Contaminant Level ("MCL") of five parts per trillion for 1,2,3-trichloropropane (TCP) and the subsequent detection of TCP levels exceeding the MCL in many Arvin-Edison groundwater wells that are part of the Water Banking Program (Program). As a result of the detection of TCP in Arvin-Edison wells, Metropolitan has temporarily suspended operation of the Program until the water quality concerns can be further evaluated and managed. More specifically, the high levels of TCP prevent Metropolitan from taking return of contaminated groundwater under the Program because the Department of Water Resources (DWR) prohibits the introduction of water into the California Aqueduct which exceeds the MCL. Thus, Metropolitan requests that Arvin-Edison provide only surface water or groundwater that can satisfy DWR's standards for direct pumpback into the California Aqueduct, or alternative methods satisfactory to Metropolitan, in order to meet both the DWR pump-in requirements and Metropolitan's request for the return of water in 2021.

Furthermore, given the dry hydrologic conditions last year and this year to date, Metropolitan does not anticipate storing any water in Arvin-Edison's groundwater basin this year. Even if hydrologic conditions improve, Metropolitan does not plan on storing additional water in Arvin-Edison's groundwater basin due to TCP levels in the basin that exceed the MCL which prevent the parties from operating the Program.

Metropolitan appreciates Arvin-Edison's ongoing cooperation in managing this Program for the benefit of each agency. Please contact Mr. James Bodnar at (213) 217-6099 or via email at jbodnar@mwdh2o.com to coordinate the schedule and amount of stored water to be returned, or if you need further information.

Very truly yours,

DocuSigned by:
Deven N Upadhyay
A4844BCDF3984DE...

Deven N. Upadhyay
Assistant General Manager/Chief Operating Officer

JDB:vsm

ARVIN-EDISON WATER STORAGE DISTRICT

July 22, 2021
Via Electronic Mail (DUpadhyay@mwdh2o.com)

Deven Upadhyay
Chief Operating Officer
The Metropolitan Water District of Southern California
P.O. Box 54153
Los Angeles, California 90054-0153

Re: 2021 Request for Return of Stored Water from the Arvin-Edison Water Banking Program

Dear Mr. Upadhyay:

Pursuant to the "First Amended and Restated Agreement between Arvin-Edison Water Storage District and The Metropolitan Water District of Southern California for a Water Management Program" (Agreement), Metropolitan's request dated April 12, 2021, and our subsequent discussions, this letter agreement outlines a method to return water to Metropolitan from the Program that does not involve Arvin-Edison Water Storage District (Arvin-Edison) pumping groundwater into the California Aqueduct. As you are aware, the need for this alternative method is a direct result of the detection of 1,2,3-trichloropropane (TCP) in concentrations that exceed the Maximum Contaminant Level (MCL) of five parts per trillion in Arvin-Edison's wells. Such concentrations of TCP prevent Metropolitan from taking return of contaminated groundwater under the Program because the Department of Water Resources (DWR) prohibits the introduction of water into the California Aqueduct which exceeds the MCL. Section 4.5 of the Agreement provides that where the return of Regulated Water cannot meet DWR's pumpback standards, Arvin-Edison and Metropolitan may agree to alternative methods of returning water to Metropolitan, including by exchange. Therefore, pursuant to Section 4.5 of the Agreement, Metropolitan and Arvin-Edison agree to the following:

1. During calendar year 2021, Arvin-Edison may provide an estimated 40,000 acre-feet of surface water to Metropolitan from the Central Valley Project (CVP). The actual amount and schedule will be coordinated and approved by Metropolitan and Arvin-Edison in writing in advance of the delivery. Arvin-Edison will provide any such water from Millerton Lake to the Friant-Kern Canal to the Cross-Valley Canal to the California Aqueduct. The water provided to Metropolitan will be high quality and will satisfy DWR's pumpback standards. Ten percent (10%) of the water that Arvin-Edison provides to Metropolitan will be considered a return of Regulated Water under the Agreement. As such, Metropolitan will pay the charges under the Agreement as if the water had been returned by recovery of Regulated Water, provided that Metropolitan may utilize credits it has accumulated under the Water Quality Sub Account to offset such charges. However, Arvin-Edison will provide no groundwater to Metropolitan under this letter agreement.

2. Simultaneous with Arvin-Edison providing the water to Metropolitan as described in Paragraph 1 above, Metropolitan will provide to Arvin-Edison an amount of water in San Luis Reservoir equivalent to 10% less than the amount Arvin-Edison provides to Metropolitan pursuant to Paragraph 1. Arvin-Edison will then provide this water from San Luis Reservoir to the San Joaquin River Settlement Contractors through the Delta-Mendota Canal. Arvin-Edison is responsible for obtaining all necessary approvals for delivery of water from San Luis Reservoir to the San Joaquin River Settlement Contractors. At the end of each month in which any deliveries occur, a reconciliation of the deliveries Metropolitan provided to Arvin-Edison and the water Arvin-Edison returned to Metropolitan will occur. Any difference will be scheduled in the following month.

20401 East Bear Mountain Boulevard · P.O. Box 175 · Arvin, CA 93203-0175
Telephone (661) 854-5573 · Fax (661) 854-5213 · E-mail: arvined@aewsd.org · www.aewsd.org

3. Arvin-Edison will not receive any additional surface water as a result of the actions described in this letter agreement. Metropolitan and Arvin-Edison recognize that the Bureau of Reclamation may increase the CVP declaration to Friant contractors for reasons unrelated to the actions described in this letter agreement which may result in Arvin-Edison receiving additional surface supplies.

If the above meets with your understanding, please countersign below and return an original to Arvin-Edison. Please contact me if you need further information.

Sincerely,

Jeevan Muhar, P.E.
Engineer-Manager

ACKNOWLEGED AND AGREED TO:

Arvin-Edison Water Storage District

Jeevan Muhar, Engineer-Manager

The Metropolitan Water District of Southern California

Deven Upadhyay, Chief Operating Officer

cc: David A Nixon, Arvin-Edison
Scott Kuney, Young Wooldridge
James Bodnar, Metropolitan
Kira Alonzo, Metropolitan
Jason Phillips, Friant Water Authority

2020
URBAN WATER MANAGEMENT PLAN

JUNE 2021

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

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3.3 Central Valley/State Water Project Storage and Transfer Programs

Metropolitan endeavors to increase the reliability of supplies received from the California Aqueduct by developing flexible SWP storage and transfer programs. Over the years, Metropolitan has developed numerous voluntary SWP storage and transfer programs to secure additional dry-year water supplies.

Background

Metropolitan has a long history of managing the wide fluctuations of SWP supplies from year to year by forming partnerships with Central Valley agricultural districts along the California Aqueduct, as well as with other Southern California SWP Contractors. These partnerships allow Metropolitan to store its SWP supplies during wetter years for return in future drier years. Some programs also allow Metropolitan to purchase water in drier years for delivery via the California Aqueduct to Metropolitan's service area.

Because yields from individual programs can vary widely depending on hydrologic conditions and CVP/SWP operations, the dry-year yields for the various programs reported in this section are expected values only. In any given year, actual yields could depart from the expected values. Despite that uncertainty, Metropolitan's models of these programs indicate that in the aggregate, they can meet the resource target under a wide range of hydrologic conditions and CVP/SWP operations.

In addition, the SWP storage and transfer programs have served to demonstrate the value of partnering, and, increasingly, Central Valley agricultural interests see partnering with Metropolitan as a sensible business practice beneficial to their local district and regional economy.

Implementation Approach

Metropolitan is currently operating several SWP storage programs that serve to increase the reliability of supplies delivered through the California Aqueduct. Metropolitan pursues SWP water transfers on an as-needed basis. Table 3-3 lists the expected yields from these storage and transfer programs. Figure 3-3 shows the location of Metropolitan's statewide groundwater banking programs.

Storage and Transfer Programs

Semitropic Storage Program

Metropolitan has a groundwater storage program with Semitropic Water Storage District located in the southern part of the San Joaquin Valley. The maximum storage capacity of the program is 350 TAF. The specific amount of water Metropolitan can store in and subsequently expect to receive from the program depends upon hydrologic conditions, any regulatory requirements restricting Metropolitan's ability to export water for storage, and the demands placed on the Semitropic Program by other program participants. In 2014, Metropolitan amended the program to increase the return yield by an additional 13.2 TAF per year. The minimum annual yield available to Metropolitan from the program is currently 34.7 TAF, and the maximum annual yield is 236.2 TAF, depending on the available unused capacity and the SWP allocation. During wet years, Metropolitan has the discretion to use the program to store portions of its SWP water that are in excess of the amounts needed to meet Metropolitan's service area demand. In Semitropic, the water is delivered to district farmers who use the water in lieu of pumping groundwater. During dry years, the district returns Metropolitan's previously stored water to Metropolitan by direct groundwater pump-in return and the exchange of SWP supplies.

Arvin-Edison Storage Program

Metropolitan amended the groundwater storage program with Arvin-Edison Water Storage District in 2008 to include the South Canal Improvement Project. The project increases the reliability of Arvin-Edison returning higher water quality to the California Aqueduct. In addition, Metropolitan and Arvin-Edison often enter into annual operational agreements to optimize program operations in any given year. The program storage capacity is 350 TAF. The specific amount of water Metropolitan can expect to store in and subsequently receive from the program depends upon hydrologic conditions and any regulatory requirements restricting Metropolitan's ability to export water for storage. The storage program is estimated to deliver 75 TAF. During wet years, Metropolitan has the discretion to use the program to store portions of its SWP supplies which are in excess of the amounts needed to meet Metropolitan's service area demand. The water can be either directly recharged into the groundwater basin or delivered to district farmers who use the water in lieu of pumping groundwater. During dry years, the district returns Metropolitan's previously stored water to Metropolitan by direct groundwater pump-in return or by exchange of surface water supplies. In 2015, Metropolitan funded the installation of three new wells at a cost of $3 million that will restore the return reliability by 2.5 TAF per year. The funding will ultimately be recovered through credits against future program costs. As a result of recent detection of 1,2,3-trichloropropane in Arvin-Edison wells, Metropolitan has temporarily suspended operation of the program until the water quality concerns can be further evaluated and managed.

Table 3-3 summarizes Metropolitan's Central Valley/SWP transfer programs supply range for 2035. The supply capabilities shown reflect actual storage program conveyance constraints. In addition, SWP supplies are estimated using DWR's 2019 SWP Delivery Capability Report released in August 2019. Appendix 3 provides a detailed discussion of the current Central Valley and SWP storage and transfers programs and programs that are under development.

Table 3-3
Central Valley/State Water Project Storage and Transfer Programs
Supply Projection
Year 2035
(acre-feet per year)

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program[1]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	43,000	70,000	70,000
Kern Delta Program	42,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***187,000***	***217,000***	***240,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**187,000**	**217,000**	**253,000**

[1] Take and put amounts limited due to water quality considerations.

San Bernardino Valley MWD Transfer Program

The San Bernardino Valley MWD Transfer Program allows for the purchase of a portion of San Bernardino Valley MWD's SWP supply under surplus conditions. Each calendar year, a determination will be made on how much surplus supplies are available, and Metropolitan will then decide how much will be purchased. The agreement term is until December 31, 2035 and can be extended with a State Water Contract extension.

San Gabriel Valley MWD Exchange Program

The San Gabriel Valley MWD program allows for the exchange of up to 5 TAF each year. For each acre-foot Metropolitan delivers to the City of Sierra Madre, a San Gabriel Valley MWD member agency, San Gabriel Valley MWD provides two acre-feet to Metropolitan in the Main San Gabriel Basin, up to 5 TAF. The program provides increased reliability to Metropolitan by allowing additional water to be delivered to Metropolitan's member agencies Three Valleys MWD and Upper San Gabriel Valley MWD.

Antelope Valley-East Kern Water Agency Exchange and Storage Program

The Antelope Valley-East Kern Water Agency (AVEK) exchange and storage program provides Metropolitan with additional supplies and increased reliability. Under the exchange program, for every two acre-feet Metropolitan receives, Metropolitan returns one acre-foot to AVEK to improve its reliability. The exchange program is expected to deliver 30 TAF over ten years, with 10 TAF available in dry years. Under the program, Metropolitan will also be able to store up to 30 TAF in the AVEK's groundwater basin, with a dry year return capability of 10 TAF.

State Water Project

The key water quality issues for the SWP are disinfection byproduct precursors, in particular, total organic carbon, bromide, and low alkalinity. Metropolitan is working to protect the water quality of this source, but it has needed to upgrade its water treatment plants to deal adequately with disinfection byproducts. Disinfection byproducts result from total organic carbon and bromide in the source water reacting with disinfectants at the water treatment plant, and they may place some near-term restrictions on Metropolitan's ability to use SWP water. Low alkalinity water requires a higher percentage of total organic carbon removal in order to reduce disinfection byproduct formation. Metropolitan is overcoming these treatment restrictions through the use of ozone disinfection at its treatment plants, which has been implemented at all five of Metropolitan's treatment plants and blending SWP water with higher alkalinity Colorado River water. Arsenic is also of concern in some groundwater storage programs. Groundwater inflows into the California Aqueduct are managed to comply with regulations and protect downstream water quality while meeting supply targets. Additionally, nutrient levels are significantly higher in the SWP than within the Colorado River, leading to the potential for algal related concerns that can affect water management strategies. Metropolitan is engaged in efforts to protect the quality of SWP water from potential increases in nutrient loading from wastewater treatment plants.

Local Agency Supplies and Groundwater Storage

Drinking water standards for contaminants, such as arsenic, chromium-6, 1,2,3-trichloropropane, and other emerging constituents, such as per- and polyfluoroalkyl substances (PFAS), may add costs to the use of groundwater storage and may affect the availability of local agency groundwater sources. Although Metropolitan has not analyzed the direct effect of these water quality issues on local agency supply, these contaminants are not expected to significantly impact the availability of Metropolitan supplies, but may affect the availability of local agency supplies. This could affect demands on Metropolitan supplies if local agencies abandon impacted supplies in lieu of treatment options or use Metropolitan water to blend with their sources.

In summary, the major regional water quality concerns include the following:

- Salinity
- Perchlorate
- Total organic carbon and bromide (disinfection byproduct precursors)
- Nutrients (as they relate to algal productivity)
- Arsenic
- Uranium
- Chromium-6
- 1,2,3-trichlorpropane
- Constituents of emerging concern (e.g., NDMA, microplastics, and PFAS)

Metropolitan has taken several actions and adopted programs to address these contaminants and to ensure a safe and reliable water supply. These actions, organized by contaminant, are discussed below, along with other water quality programs that Metropolitan has been engaged in to protect its water supplies.

In the past 5 years, results of source and treated water monitoring for chromium-6 indicate the following:

- Levels in Colorado River water are mostly not detected (<0.03 μg/L), but when detected, levels range from 0.03 to 0.085 μg/L. SWP levels range from 0.03 to 1.0 μg/L. Treated water levels range from 0.03 to 0.8 μg/L.
- There is a slight increase in chromium-6 in the treated water from the oxidation (chlorination and ozonation) of natural background chromium (total) to chromium-6.
- Colorado River monitoring results upstream and downstream of the site of a Pacific Gas and Electric (PG&E) gas compressor station located along the Colorado River near Topock, Arizona (discussed below) have ranged from not detected (<0.03 μg/L) to 0.06 μg/L.
- Chromium-6 in Metropolitan's groundwater pump-in storage programs in the Central Valley has ranged from not detected (< 1 μg/L) to 8.9 μg/L in 2014, with the average for the different programs ranging from < 1 μg/L to 3 μg/L.

PG&E used chromium-6 as an anti-corrosion agent in its cooling towers at the Topock site from 1951 to 1985. Wastewater from the cooling towers was discharged from 1951 to 1968 into a dry wash next to the station. Monitoring wells show the plume concentration has peaked as high as 16,000 μg/L in groundwater. Since 2004, PG&E has operated an interim groundwater extraction and treatment system that is protecting the Colorado River. This interim treatment system will be taken offline in September 2021 and replaced by the long-term groundwater remedy system. Quarterly monitoring of the river has shown levels of chromium-6 less than 1 μg/L, which are considered background levels. The California Department of Toxic Substances Control (DTSC) and the U. S. Department of the Interior are the lead state and federal agencies overseeing the cleanup efforts. Metropolitan participates through various stakeholder workgroups and partnerships that include state and federal regulators, Indian tribes, and other stakeholders (e.g., Colorado River Board) involved in the corrective action process. In January 2011, a final treatment remedy was selected, and an Environmental Impact Report was certified. In November 2015, PG&E completed the final remedy design based on the selected remedy which involves the installation of an in-situ bioremediation treatment system. In April 2015, DTSC required the preparation of a Subsequent Environmental Impact Report (EIR) to address new design details. The Subsequent EIR was certified in April 2018. Construction of Phase 1, consisting of an In-situ reduction zone, began in October 2018 and is expected to be completed in 2021. Phase 2, consisting of a freshwater injection system, is anticipated to begin construction in 2023 and last about one year. Operation of the treatment system will run for an estimated 30 years.

The federal- and state-approved technologies for removing total chromium from drinking water include coagulation/filtration, ion exchange, reverse osmosis, and lime softening. For several years, the cities of Glendale, Burbank, and Los Angeles have been voluntarily limiting chromium-6 levels in their drinking water to 5 μg/L, even after the MCL was rescinded in 2017.

1,2,3-Trichloropropane (1,2,3-TCP)

1,2,3-TCP is a chlorinated hydrocarbon with high chemical stability. It is a manmade chemical found at industrial or hazardous waste sites. It has been used as a cleaning and degreasing solvent and also is associated with pesticide products.

At its July 18, 2017 public meeting, the SWRCB adopted an MCL of 5 parts per trillion (ppt) for 1,2,3-TCP, and related requirements, including establishing a DLR, identifying the best available technology for treatment, and setting public notification and consumer confidence report language. The regulations also included a method for public water systems to substitute existing water quality data for initial monitoring requirements under certain circumstances. Under the new regulation, drinking water agencies are required to perform quarterly monitoring of 1,2,3-TCP. There have been no detections of this chemical in Metropolitan's system. However, 1,2,3-TCP has been detected above the new MCL in groundwater wells of three of Metropolitan's groundwater storage program partners through monitoring performed by these agencies. Levels detected in groundwater wells of the Arvin-Edison Water Storage District are the highest and impact the ability of Metropolitan to put water and take return water under that program. Metropolitan has temporarily suspended operation of this program until the water quality concerns can be further evaluated and managed. The levels of 1,2,3-TCP detected in Metropolitan's other groundwater storage programs are much lower and impact fewer groundwater wells. Metropolitan is evaluating the effects of TCP on the return capability of those programs. Southern California counties that have detected concentrations of 1,2,3-TCP in drinking water sources at or over 5 ppt since 2010 include San Bernardino (48 sources), Los Angeles (63 sources), Riverside (24 sources), San Diego (10 sources), and Ventura (3 sources).[11]

Constituents of Emerging Concern

N-Nitrosodimethylamine

N-Nitrosodimethylamine (NDMA) is part of a family of organic chemicals called nitrosamines. NDMA is a chloramine disinfection by-product, and it is the most abundantly detected nitrosamine in drinking water systems. Metropolitan utilizes chloramines as a secondary disinfectant at its treatment plants. Wastewater treatment plant discharges can contribute organic matter into source waters, which react with chloramines to form NDMA at drinking water treatment plants. Certain coagulation aid polymers used in water treatment, e.g., polydiallyldimethylammonium chloride (polyDADMAC), can also contribute to NDMA formation. Some NDMA control measures are being used to avoid adverse impacts on Southern California drinking water supplies. Metropolitan is involved in several projects to understand the impact of different treatment processes on NDMA and its precursors at drinking water treatment plants and in distribution systems. Certain pre-oxidation processes, such as chlorine and ozone, have been shown to destroy NDMA precursors. Additional studies are being conducted to better understand how polyDADMAC contributes to NDMA formation and to identify measures to reduce polymer-derived NDMA formation.

USEPA considers NDMA to be a probable human carcinogen. USEPA placed NDMA on the Contaminant Candidate List 4 (CCL4). Although there is no federal regulation for nitrosamines in drinking water, DDW set a notification level of 0.01 μg/L each for NDMA and two other nitrosamines. Occurrences of NDMA in treated water supplies at concentrations greater than 0.01 μg/L are recommended to be included in a utility's annual Consumer Confidence Report. In December 2006, OEHHA set a PHG for NDMA of 0.003 μg/L. Since 1999, Metropolitan has conducted voluntary monitoring of the five treatment plant effluents and representative distribution system locations semi-annually. NDMA is the only detected nitrosamine in Metropolitan's treated water systems, and it is in the range of non-detect (<0.002 μg/L) to 0.006 μg/L. NDMA or a broader class of nitrosamines may likely be the next class of disinfection by-products to be regulated by USEPA.

[11] DDW data reported from SWRCB Groundwater Ambient Monitoring Assessment Program's web site: https://gamagroundwater.waterboards.ca.gov/. Numbers reported may change as the website is frequently updated. Also, the website includes additional source data reported by other entities.

Financing

Metropolitan's O&M budget (referenced above) includes payments for the Semitropic Program.

Federal, State, and Local Permits/Approvals

Final EIR. Semitropic acting as the lead agency under CEQA and Metropolitan acting as a responsible agency jointly completed the EIR for the Program. The EIR was certified by Semitropic in July 1994 and adopted by Metropolitan in August 1994.

Regulatory Approvals. All regulatory approvals are in place, and the program is operational.

E. Arvin-Edison Water Management Program

Source of Supply

The Arvin-Edison Water Storage District (Arvin-Edison) manages the delivery of local groundwater and water imported into its service area from the Central Valley Project's (CVP) Millerton Reservoir via the Friant-Kern Canal. The surface water service area consists of 132,000 acres of predominantly agricultural land, and to a minor degree, municipal and industrial uses. It is situated in Kern County. Arvin-Edison operates its supplies conjunctively, storing water in the underlying aquifer when imported supplies are available and withdrawing that water when the availability of imported supplies is reduced. In 1997, Metropolitan entered into an agreement with the Arvin-Edison Water Storage District. The agreement allows Metropolitan to store available water in Arvin-Edison's groundwater basin, either through direct spreading operations, or through deliveries to growers in Arvin-Edison's service area. Similar to Arvin-Edison's own usage, this previously stored water could be withdrawn when the availability of imported supplies to Metropolitan is reduced.

Expected Supply Capability

The Arvin-Edison/Metropolitan Program provides Metropolitan with the capacity to store up to 350 TAF of water under the current agreement. During dry years, Metropolitan can recover its stored water either through direct pumping of the groundwater or through exchange. Based on the terms and conditions of the program agreement, the return of water to Metropolitan ranges from a minimum of 40 TAF per year (peak 4-month summer period) up to 110 TAF (over a 12-month period). Metropolitan staff are currently working to overcome a new challenge of detections of 1,2,3-trichloropropane (TCP) above the Maximum Contaminant Level (MCL) of five parts per trillion (ppt) in wells that are part of the Arvin-Edison/Metropolitan Program. These levels of TCP impact Metropolitan's ability to put water and take return water under that program. As a result, Metropolitan has temporarily suspended operation of the program until the water quality concerns can be further evaluated and managed.

Rationale for the Expected Supply

Historical Record

The Arvin-Edison/Metropolitan Water Management Program has been operational since 1997. With existing agreements, it will continue to operate over the term of 38 years (1997 to 2035). By the end of 2020, the program had 142 TAF in its storage account.

Written Contracts or Other Proof

1997 Arvin-Edison/Metropolitan Water Management Agreement. This Agreement was executed in December 1997 by Arvin-Edison and Metropolitan to implement the program for a 30-year term (1997-2027).

1998 Turn-in/out Construction and Maintenance Agreement. This Agreement was executed in 1998 by DWR, Kern County Water Agency, Arvin-Edison, and Metropolitan to allow construction, operation and maintenance of the Arvin-Edison California Aqueduct Turn in/out.

1998-2002 Water Delivery and Return Agreements. These agreements, with DWR, Kern County Water Agency, Arvin-Edison, and Metropolitan, allow Metropolitan to divert water from, and introduce water to, the California Aqueduct.

2004 Point of Delivery Agreement. This agreement, with DWR, Kern County Water Agency, and Metropolitan, allows Metropolitan to divert water from the California Aqueduct into Arvin-Edison's service area.

2004 Introduction of Water into the California Aqueduct. This agreement, with DWR, Kern County Water Agency, and Arvin-Edison, allows Metropolitan to receive water from the program into the California Aqueduct.

2007 First Amended and Restated Agreement Between Arvin-Edison Water Storage District and The Metropolitan Water District of Southern California for a Water Management Program. This amendment increased the maximum storage level to 350 TAF, extended the agreement term to 2035, and provided for the construction of the South Canal Improvement Project. The project increases the reliability of Arvin-Edison returning higher water quality to the California Aqueduct.

Financing

Metropolitan's O&M budget (referenced above) includes payments for the Arvin-Edison Program.

Federal, State, and Local Permits/Approvals

Environmental Status: A Negative Declaration was completed in 1996.

An Addendum to the 1996 Negative Declaration was completed in 2003.

A Negative Declaration for the Arvin-Edison South Canal Improvement Project was completed in 2007.

Regulatory Approvals: All regulatory approvals are in place, and the program is operational.

F. San Bernardino Valley Municipal Water District Program

Source of Supply

The San Bernardino Valley Municipal Water District Program allows Metropolitan to purchase a dependable annual supply, as well as an additional supply for dry year needs. Under this program, Metropolitan purchases water provided to San Bernardino Valley Municipal Water District (Valley District) from its annual SWP water allocation. Valley District delivers the purchased supplies to Metropolitan's service area through the coordinated use of facilities and interconnections within the water conveyance system of the two districts.

The purchased SWP supply is provided to Metropolitan as direct deliveries of annual SWP water through the California Aqueduct to Metropolitan's service area, as well as deliveries of SWP water to the San Bernardino groundwater basin that will subsequently be delivered to Metropolitan's service area. Under this program, Metropolitan purchases surplus Valley District supplies on a fixed price schedule based on the final SWP allocation each calendar year.

To facilitate the transfer, the program also provides the coordinated use of existing facilities, including the Valley District's Foothill Pipeline and the Inland Feeder, to improve the conveyance capabilities of the delivery of SWP water to the service areas of both districts. The intertie

Table A.3-7
California Aqueduct
Program Capabilities
Year 2025
(acre-feet per year)

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
MWD Table A [1]	459,000	122,000	1,108,000
DWCV Table A	47,000	12,000	113,000
San Luis Carryover [2]	56,000	282,000	282,000
Article 21 Supplies	0	0	25,000
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Yuba River Accord Purchase	12,800	14,000	6,000
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program[3]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	20,000	70,000	70,000
Kern Delta Program	38,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***734,800***	***647,000***	***1,774,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**734,800**	**647,000**	**1,787,000**

[1] Includes Port Hueneme Lease.
[2] Includes DWCV carryover.
[3] Take and put amounts limited due to water quality considerations.

Table A.3-7
California Aqueduct
Program Capabilities
Year 2030
(acre-feet per year)

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
MWD Table A [1]	479,000	122,000	1,108,000
DWCV Table A	49,000	12,000	113,000
San Luis Carryover [2]	57,000	283,000	283,000
Article 21 Supplies	0	0	22,000
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Yuba River Accord Purchase	0	0	0
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program[3]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	43,000	70,000	70,000
Kern Delta Program	42,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***772,000***	***634,000***	***1,766,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**772,000**	**634,000**	**1,779,000**

[1] Includes Port Hueneme Lease.
[2] Includes DWCV carryover.
[3] Take and put amounts limited due to water quality considerations.

Table A.3-7
California Aqueduct
Program Capabilities
Year 2035

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
MWD Table A [1]	499,000	122,000	1,108,000
DWCV Table A	51,000	12,000	113,000
San Luis Carryover [2]	57,000	283,000	283,000
Article 21 Supplies	0	0	20,000
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Yuba River Accord Purchase	0	0	0
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program [3]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	43,000	70,000	70,000
Kern Delta Program	42,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***794,000***	***634,000***	***1,764,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**794,000**	**634,000**	**1,777,000**

(acre-feet per year)

[1] Includes Port Hueneme Lease.
[2] Includes DWCV carryover.
[3] Take and put amounts limited due to water quality considerations

Table A.3-7
California Aqueduct
Program Capabilities
Year 2040
(acre-feet per year)

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
MWD Table A [1]	519,000	122,000	1,108,000
DWCV Table A	53,000	12,000	113,000
San Luis Carryover [2]	57,000	283,000	283,000
Article 21 Supplies	0	0	18,000
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Yuba River Accord Purchase	0	0	0
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program [3]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	43,000	70,000	70,000
Kern Delta Program	42,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***816,000***	***634,000***	***1,762,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**816,000**	**634,000**	**1,775,000**

[1] Includes Port Hueneme Lease.
[2] Includes DWCV carryover.
[3] Take and put amounts limited due to water quality considerations.

Table A.3-7
California Aqueduct
Program Capabilities
Year 2045
(acre-feet per year)

Hydrology	Five Year Drought (1988-1992)	Single Dry Year (1977)	Normal Year (1922-2017)
Current Programs			
MWD Table A [1]	519,000	122,000	1,108,000
DWCV Table A	53,000	12,000	113,000
San Luis Carryover [2]	56,000	282,000	282,000
Article 21 Supplies	0	0	18,000
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000
Yuba River Accord Purchase	0	0	0
Central Valley Storage and Transfers			
Semitropic Program	50,000	45,000	68,000
Arvin Edison Program [3]	0	0	0
Mojave Storage Program	0	0	0
Antelope Valley/East Kern Acquisition and Storage	20,000	70,000	70,000
Kern Delta Program	42,000	50,000	50,000
Transfers and Exchanges	50,000	50,000	50,000
Subtotal of Current Programs	***792,000***	***633,000***	***1,761,000***
Programs Under Development			
San Bernardino Valley Water District Program	0	0	13,000
Subtotal of Proposed Programs	***0***	***0***	***13,000***
Maximum Supply Capability	**792,000**	**633,000**	**1,774,000**

[1] Includes Port Hueneme Lease.
[2] Includes DWCV carryover.
[3] Take and put amounts limited due to water quality considerations.

Table A.3-8
California Aqueduct
Supply Characterization[1] Year 2021-2025
Repeat of 1988-1992 Hydrologies
(acre-feet per year)

Hydrology	2021	2022	2023	2024	2025
Current Programs					
MWD Table A[2]	221,000	940,000	274,000	442,000	345,000
DWCV Table A	22,000	95,000	28,000	45,000	35,000
Article 21 Supplies	0	0	0	0	0
San Gabriel Valley MWD Exchange and Purchase	2,000	2,000	2,000	2,000	2,000
Subtotal of SWP Core Supplies	***245,000***	***1,037,000***	***304,000***	***489,000***	***382,000***
San Luis Carryover[3]	200,000	0	69,000	0	0
Yuba River Accord Purchase	14,000	11,000	14,000	11,000	14,000
Central Valley Storage and Transfers					
Semitropic Program	40,000	0	40,000	44,000	41,000
Arvin Edison Program[4]	0	0	0	0	0
Mojave Storage Program	0	0	0	0	0
Antelope Valley/East Kern Acquisition and Storage	27,000	0	27,000	0	11,000
Kern Delta Program	50,000	0	50,000	50,000	40,000
Transfers and Exchanges	50,000	50,000	50,000	50,000	50,000
Subtotal of SWP Flexible and Storage Programs	***381,000***	***61,000***	***250,000***	***155,000***	***156,000***
Programs Under Development					
San Bernardino Valley Water District Program	0	0	0	0	0
Subtotal of Proposed Programs	***0***	***0***	***0***	***0***	***0***
Maximum Supply Capability	**626,000**	**1,098,000**	**554,000**	**644,000**	**538,000**

[1] Supply characterization for the Drought Risk Assessment is based on core supplies as defined in WSCP Appendix 4. Flexible and storage supplies from CR, SWP, and In-Region may be exercised as supply augmentation action to any potential core supply shortfall.
[2] Includes Port Hueneme lease.
[3] Includes DWCV carryover.
[4] Take and put amounts limited due to water quality considerations.